Available online at www.worldscientificnews.com

World Scientific News

WSN 50 (2016) 33-48 EISSN 2392-2192

The Fundamental Holographic Uncertainty Principle and its Primary Applications

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ABSTRACT

The fundamental holographic principle is first proposed, then demonstrated in its validity and viability through a thought experiment and then finally derived. The Heisenberg uncertainty relations are shown to follow from this fundamental relation. The quantum blackhole entropy is then demonstrated using this holographic uncertainty relation along with the application of the Landauer's principle for the thermodynamic erasure of a bit yielding a formula with a logarithmic correction. The blackhole entropy is found to be half the value normally delivered by any other method. So, it is proposed that there is a real relevant physical horizon at the twice the Schwarzschild radius dubbed the *holographic information geometric horizon*.

***Keywords*:** holographic principle; holographic uncertainty principle; Heisenberg uncertainty principle; Landauer's Principle; blackhole entropy; loop quantum gravity; area operator; quantum geometry; general relativity; corrected blackhole horizon

1. INTRODUCTION

The holographic principle [1] is the fundamental principle in physics. It's statement that data in the bulk of the space can be described by the data on the boundary of that space. So, based on this premise, Verlinde [2] showed that gravity is an entropic force. However, his derivation of Einstein's General Relativity (GR) was not palpable to the author and so in [3], the author in trying to give an alternative approach based purely on information and spacetime geometry and making minimum of assumptions ended up generating four laws of statistical geometrodynamics and a formula relating boundary mean curvature and geometrodynamic probability. There was no assumptions that advocated any theory such as string theory or D-p-branes and M-theory or Loop Quantum Gravity and spin networks, etc. This enabled the theory to be amenable to the adoption of any of the above approaches in modern theoretical physics. This was just a general scheme. Now, a key test follows: can the uncertainty principle in the bulk space, so important to the whole edifice of quantum physics and certainly to the whole of physics itself, be derived from the holographic principle? The paper written here investigates that and more. First, an uncertainty in the bulk is also a physical data and hence by the holographic principle, can best be described by some kind of uncertainty on the boundary surface of the bulk space. Next, we make the following observation: the only observables on the boundary surface are the area and the number of information.bits. For the number of information bits we can take the familiar number operator n in quantum mechanics. For the area, Loop Quantum Gravity (LQG) gives us a linear operator for area which predicts a fundamental discreteness of quantum geometry. Now, the theory of LQG is mathematically rigorous and consistent and so what is true in the Ashtekar-Isham-Lewandowski measure format should be true here as well for the holographic boundary surface. But we need a physical justification for this; some sort of physical realistic demonstration. So, we consider a thought experiment.

2. FULL TEXT

It is our common experience that the area and the number of pixels or in the more fundamental case the information bits are not mutually compatible. The present work makes an endeavor to derive the most fundamental uncertainty relation on the basis of this experience and deem it rightly to be the case for the holographic surface enclosing a bulk space. The realm of quantum mechanics in which the Heisenberg uncertainty relations hold, is actually a part of a more grand picture – that of the fundamental uncertainty on the horizon between a geometric quantity and an information theoretic, but, combinatorial quantity.

2. 1. A THOUGHT EXPERIMENT ON THE TELEVISION TUBE

Consider a television tube. When we look at the picture on it we see a clearly demarked and classical picture. Looking closer towards the grids we get a certain blurred view. Looking at the pixel gives the number but not the area due to the blurred effect. The area is determined by the correct demarcation of the contours in the picture and the picture becomes perfectly visible. The number of bits becomes indeterminate in this case. The area is thus conjugate to the number of bits. In other words, there is an uncertainty between area and the number of bits. This uncertainty in area ΔA and the bit number Δn is quantum gravitational in nature as there fundamental discreteness in area spectrum is Planckian and the fact used by Verlinde that one bit occupies a Planck area of surface for information. How does the quantum gravity affect the bulk so that the fundamental uncertainty on the holographic surface delivers a Heisenberg uncertainty in the bulk space? We shall address this question shortly. We now sum our arguments of the thought experiment by shaping them into the exact statement of the holographic uncertainty principle**,** as

$$\Delta A \; \Delta n \geq \frac{G\hbar}{c^3}. \tag{1}$$

2. 2. DERIVATION OF THE FUNDAMENTAL HOLOGRAPHIC UNCERTAINTY PRINCIPLE

First, let us look at the LQG area operator. For a $j - tuple$, j_k, it is defined as

$$\widehat{\boldsymbol{A_k}} = 8\pi \frac{G\hbar}{c^3} \gamma \sqrt{\textstyle\sum_k j_k(j_k+1)}, \tag{2}$$

where, γ is the Barbero-Immirzi parameter. For our purposes of information bits, we take a simpler operator for area as

$$\hat{A} = \sqrt{b(b+1)} \frac{G\hbar}{c^3}. \tag{3}$$

Here, the quantum number,b, is the bit geometry quantum number. It is easy to see that this area is also a Ashtekar-Isham-Lewandowski compatible operator since it will deliver area eigenvalues on the holographic surface which are gauge invariant or Dirac observables. The measure for (3) is simply a numerically or scale transformed version of the LQG Ashtekar-Lewandowski measure defined for (2). It is also easy to verify that the area operator defined by (3) is a linear operator.

Next, take creation and annihilation operators $a^{\dagger}$ and a respectively for creation and annihilation of an information bit on the holographic surface. Then, the product $a^{\dagger}a$ taken jointly delivers the number operator n for the information bit. The area and the number of bits on the holographic screen w.r.t. the area containing the information bits have a mutual exclusivity. It is however, Planck scale in nature of the individual dispersion. To obtain an explicit and exact inequality, we must call upon the general formalism of quantum mechanics and apply it to the holographic screen.

First, we postulate the following propositions:

For every bit of information on the holographic surface, there exists a hermitian/ self-adjoint wavefunction. It is a position independent function. It depends only on the topological and global geometric properties of the holographic surface. As such, the Chern-Simons term is also lower dimensional and topological. So, a Chern-Simons term involving a connection on the holographic surface, $A_a = \mathcal{A}$ is a good argument for the qubit function φ. Let $\mathcal{S}_{CS}$ be the Chern-Simons actional; thus, $\varphi(\mathcal{A}) = k \int e^{i\mathcal{S}_{CS}} d\mu(\mathcal{A})$ is a good path integral representation of $\varphi(\mathcal{A})$. The bit dynamics is thus global.

1. The bits on the holographic surface are background independent and being CS global they observe non-locality.
2. There exist two prime linear self adjoint operators viz., area "$\hat{A}$" and number "$\hat{n}$"which give complete information of the bit.
3. The operators $\hat{A}$ and $\hat{n}$ are mutually exclusive and have Planck scale dispersions w.r.t. the bit measurement on the holographic screen. They obey eq (1), viz., $\Delta A\, \Delta n \geq \frac{G\hbar}{c^3}$..

It is precisely this inequality that we wish to prove.

PROOF: Now, for any operator A, the mean value of the product $AA^\dagger$ is never negative i.e., $AA^\dagger \nless 0$, for by definition of $A^\dagger$,

$$\overline{AA^\dagger} = \int \varphi^*\{(AA^\dagger)\varphi\}dg = \int \varphi^* A(A^\dagger\varphi)dg$$

$$= \int (A^\dagger\varphi)^* \cdot (A^\dagger\varphi)dg = \int \left|A^\dagger\varphi\right|^2 dg \geq 0 \tag{4}$$

We take this general operator A as the our area operator itself from now on. We now deduce inequalities referring to the mean values of two real operators – area, A and bit number operator, n – inequalities which lead to the holographic uncertainty relation.

From the definition of $A^\dagger$, it follows on multiplication by i that

$$\int \varphi^*(iA\psi)dg = -\int (iA^\dagger\varphi)^*\psi dg \tag{5}$$

that is to say $(iA)^\dagger = -iA^\dagger$. More generally, we can have

$$(A + in)^\dagger = A^\dagger - in^\dagger. \tag{6}$$

Since, A and n are real, and for $\lambda \in \mathbb{R}$, then

$$\overline{(A + \iota\lambda n)(A + \iota\lambda n)^\dagger} \geq 0 \tag{7}$$

or

$$\overline{(A + \iota\lambda n)(A - \iota\lambda n)} = \overline{A^2} + \overline{n^2\lambda^2} - i\lambda\overline{(An - nA)} \geq 0 \tag{8}$$

From this it follows that the average of the commutator $An - nA$ is purely imaginary. The minimum of the last expression occurs when

$$\lambda = \frac{i}{2}\frac{\overline{(An-nA)}}{\overline{n^2}} \tag{9}$$

and is equal to

$$\overline{A^2} + \frac{1}{4}\frac{\overline{(An-nA)}^2}{\overline{n^2}} \geq 0 \tag{10}$$

Hence,

$$\overline{A^2}\,\overline{n^2} \geq -\frac{1}{4}\overline{(An - nA)}^2 \tag{11}$$

Now, replace A and n by

$\delta A = A - \bar{A}$ and $\delta n = n - \bar{n}$

then

$$\delta A\, \delta n - \delta n\, \delta A = An - A\bar{n} - \bar{A}n + \bar{A}\,\bar{n} - nA + n\bar{A} + \bar{n}A - \bar{n}\,\bar{A} = An - nA \tag{12}$$

and the preceding equation gives

$$\overline{(\delta A)^2} \cdot \overline{(\delta n)^2} \geq -\frac{1}{4}\overline{(An - nA)}^2 \tag{13}$$

Now, we take A precise ly as our Holographic surface area operator representation then n is the operator representing the number of information qubits on the Holographic surface area A. Then, we have,

$$\hat{A}\hat{n} - \hat{n}\hat{A} = -i\frac{G\hbar}{c^3} \tag{14}$$

Therefore,

$$\overline{(\delta A)^2} \cdot \overline{(\delta n)^2} \geq \left(\frac{G\hbar}{c^3}\right)^2 \tag{15}$$

For the root mean square deviations

$$\Delta A = \left(\overline{(\delta A)^2}\right)^{1/2} \tag{16}$$

$$\Delta n = \left(\overline{(\delta n)^2}\right)^{1/2} \tag{17}$$

we therefore must have:

$$\Delta A\, \Delta n \geq \frac{G\hbar}{c^3} \tag{1}$$

Hence, the Holographic Uncertainty Principle is demonstrated.

As stated in eq (1). This is the fundamental uncertainty principle on the Holographic surface – any arbitrary surface enclosing any volume of space containing a quantum system. If this uncertainty relation – the Holographic Uncertainty Principle – is indeed fundamental, then all the Heisenberg uncertainty relations should indeed be derivable from this principle. We will see, in what follows, that this is indeed the case. We therefore proceed to demonstrate the Heisenberg uncertainty relations from the Holographic Uncertainty Principle given by inequality (1). Throughout our demonstrations of the various Heisenberg uncertainties we consider our holographic surface to be something like a Gaussian surface enclosing the quantum system at the center of the surface – the surface taken in the form of a sphere $\mathcal{S}^2$. So, the Heisenberg dispersion occurs when the measurement is made on the quantum system by an observer anywhere on the surface of the holographic sphere.

2. 3. THE GRAVITATIONAL FORCE LAW OF NEWTON AND THE FUNDAMENTAL UNCERTAINTY OF HEISENBERG

Now, for the basic Heisenberg uncertainty principle, that exists between canonical coordinate q and its conjugate momentum p, viz.,

$$\Delta p \Delta q \geq \frac{\hbar}{2} \tag{18}$$

Consider the inequality (1), namely

$$\Delta A\ \Delta n \geq \frac{G\hbar}{c^3} \tag{1}$$

Now, inside the holographic $2-surface$, we have $3-dimensional$ bulk of space where in the non-relativistic limits, we may assume that the Newtonian laws of mechanics and gravitation are valid. So, for the data described by the srea and the number of bits in the area on the holographic surface, there is a gravitational force

$$F = \frac{GMm}{R^2} \tag{19}$$

in the bulk [2] – primarily a Newtonian one. We prove this as follows:

PROOF: Consider a holographic screen in the form of a spherical surface $\mathcal{S}^2$. At the center of this surface $\mathcal{S}^2$, let there be a mass M. Let us imagine a point mass m on the surface $\mathcal{S}^2$. Then, let A be the area of the surface $\mathcal{S}^2$ so that $A = 4\pi R^2$ where R is the equidistance of the mass M from all the bit grids on the surface $\mathcal{S}^2$ taken as a mesh. Let each bit occupy a fundamental area A_0. Then the number of bits on $\mathcal{S}^2$ is

$$N = \frac{A}{A_0} \tag{20}$$

Now, the mass m transiting along the grid or across it will experience a force and a consequent acceleration a. It will thus record a temperature due to the acceleration. This is the Unruh temperature,

$$T_U = \frac{a\hbar}{2\pi k_B c} \tag{21}$$

Now, the energy of the point mass per degree of freedom is

$$E = \frac{1}{2} k_B T_U \tag{22}$$

For N bits,

$$E_N = \frac{1}{2} N k_B T_U \tag{23}$$

Also by the mass-energy equivalence,

$$E_N = Mc^2 \tag{24}$$

For the mass at the center.

So,

$$Mc^2 = \frac{1}{2} N k_B \frac{a\hbar}{2\pi k_B c} \tag{25}$$

$$Mc^2 = \frac{1}{2}\frac{4\pi R^2}{A_0}\frac{a\hbar}{2\pi c} \tag{26}$$

$$\frac{M}{R^2}A_0\frac{c^3}{\hbar} = a \tag{27}$$

By Newton's second law of motion,

$$F = ma \tag{28}$$

Therefore,

$$F = m\frac{M}{R^2}A_0\frac{c^3}{\hbar} = ma \tag{29}$$

For $n = 1$ eigenvalue for the number operator $\hat{n}$ and one step of area $\Delta A = A_0$, the Holographic Uncertainty Principle tells us that $A_0 = \frac{G\hbar}{c^3}$. So, finally, setting $A_0 = \frac{G\hbar}{c^3}$ as the fundamental area occupied by one bit of information on the holographic screen $\mathcal{S}^2$, we have

$$F = m\frac{M}{R^2}\frac{G\hbar}{c^3}{}_0\frac{c^3}{\hbar} = ma \tag{30}$$

or

$$F = \frac{GMm}{R^2} \tag{19}$$

Hence, proved.

Now, we can demonstrate the Heisenberg uncertainty relation

$$\Delta p \Delta q \geq \frac{\hbar}{2}$$

PROOF: So now, more precisely, for the mass $M = m$, and the second law of Newton reading

$$F = \frac{\Delta p}{\Delta t} = \frac{GM^2}{R^2} \tag{31}$$

$$\Delta A\ \Delta n\ \frac{c^3}{\Delta p R^2}\Delta t\ M^2 \geq \hbar \tag{32}$$

$$\Delta A\ \ \frac{\Delta n M^2 c^2}{\Delta p}\frac{\Delta t}{R}\frac{c}{R} \geq \hbar \tag{33}$$

$$\Delta A\frac{(\Delta p)^2}{\Delta p}\ \frac{1}{c}\frac{c}{R} \geq \hbar \tag{34}$$

$$\Delta(4\pi R^2)\ \Delta p\ \frac{1}{R} \geq \hbar \tag{35}$$

$$\Delta(2\pi R)\ \Delta p \geq \frac{\hbar}{2} \tag{36}$$

$$\Delta p\ \Delta s \geq \frac{\hbar}{2} \tag{37}$$

The s in the above inequality is the circumference of any great circle on $\mathcal{S}^2$. Then, Δs is any typical fiber of the center of the circle. For such a fiber, there is an exact dispersion in the coordinate q of the mass M at the center. Call this Δq. Then, upto an isomorphism

$$\Delta p \, \Delta q \geq \frac{\hbar}{2} \tag{18}$$

This, delivers us our first of the Heisenberg uncertainty relations.

2. 4. THE HEISENBERG ENERGY-TIME UNCERTAINTY RELATION

Next, we derive the insecure uncertainty between energy E and time t viz.,

$$\Delta E \, \Delta t \geq \frac{\hbar}{2} \tag{38}$$

PROOF: Lets alter the Holographic Uncertainty Relation (1) once more to give

$$\Delta A \, \Delta n \, \frac{c^3}{G} \geq \hbar \tag{39}$$

Now, the force of Newtonian gravity that is standard and is, as seen above, also delivered by the Holographic Uncertainty Principle is

$$F = \frac{GM^2}{R^2} \tag{19'}$$

Therefore, work done by the gravity is

$$F \cdot R = \frac{GM^2}{R} = E \tag{40}$$

Thus, the energy E is

$$E = \frac{GM^2}{R} \tag{41}$$

And so

$$\frac{E\,R}{M^2} = G \tag{42}$$

Now,

$$\Delta A \, \Delta n \, \frac{c^3}{G} = \frac{\Delta A}{c} \Delta n \frac{c^4}{E\,R} M^2 \geq \hbar \tag{43}$$

Or,

$$\frac{\Delta A}{c} \Delta n \frac{E^2}{E\,R} \geq \hbar \tag{44}$$

or

$$\Delta A \, \frac{\Delta n \, E}{c\,R} \geq \hbar \tag{45}$$

Therefore,

$$\Delta E \ \frac{\Delta A}{c\ R} \geq \hbar \quad (46)$$

Where we have absorbed the uncertainty Δn into the uncertainty in E. Now,

$$\Delta A = \frac{\Delta\left(4\pi R^2\right)}{c\ R} = \frac{\Delta(4\pi R)}{c} = \frac{\Delta(2s)}{c} \approx 2\Delta t \quad (47)$$

Thus,

$$\Delta E\ \Delta t \geq \frac{\hbar}{2} \quad (38)$$

So, we have delivered the second quantum mechanical uncertainty relation the Heisenberg Energy-Time Uncertainty relation.

2. 5. THE HEISENBERG ANGULAR MOMENTUM – ANGULAR (AZIMUTHAL) COORDINATE UNCERTAINTY RELATION

Now, for the final basic uncertainty relation

$$\Delta J_z \Delta\varphi \geq \frac{\hbar}{2} \quad (48)$$

PROOF: One more time we alter the inequality (1) to get

$$\Delta A\ \Delta n \frac{c^3}{G} \geq \hbar \quad (39)$$

The Newtonian gravitational force is $F = \frac{GM^2}{R^2}$.

Therefore,

$$\frac{\Delta p}{\Delta t}\frac{R^2}{M^2} = G \quad (49)$$

and, therefore

$$\Delta A\ \Delta n\ \frac{M^2 c^3 \Delta t}{\Delta p\ R^2} \geq \hbar \quad (50)$$

or

$$\Delta A\ \Delta n \frac{\Delta p\ c}{R^2}\ \Delta t \geq \hbar \quad (51)$$

Now, for a spherical Holographic surface, $A = 4\pi R^2$. So

$$\Delta \frac{\left(4\pi R^2\right)}{R} \Delta p\ \Delta n \geq \hbar \quad (52)$$

where, we have taken ${}^{\Delta t}/_{R} = {}^{1}/_{c}$

$$2\pi\Delta R\ \Delta p\ \Delta n \geq \hbar \quad (53)$$

And now we consider the standard relationship between position vector, momentum and angular momentum, viz., $\boldsymbol{J} = \boldsymbol{R} \times \boldsymbol{p}$ $or\ for\ magnitudes\ only\ J = Rp$ in the following way for quantum dispersions

$$\Delta R\ \Delta p \approx \Delta J_z \tag{54}$$

Therefore,

$$\Delta J_z\ \Delta(\pi n) \geq \frac{\hbar}{2} \tag{55}$$

or, finally with $\varphi = \pi n$

$$\Delta J_z \Delta\varphi \geq \frac{\hbar}{2} \tag{48}$$

This proves our final Heisenberg uncertainty relation.

Now, the bit number operator $\hat{n}$ is due to $a^{\dagger}a$ where $a^{\dagger}$ is the creatot and a s the annihilator of holographic fundamental topological states that when combined yield a bit on the horizon or holographic screen. So, if the question is: what is created and annihilated to yield a bit number $\langle n \rangle$ on the holographic boundary, then the answer is probably these topological information states on the grid – lets call them *"toposons"*. The annihilation of a bit conserves it by information conservation which is a necessary theorem in quantum mechanics and therefore it is quickly created by $a^{\dagger}$ to appear elsewhere. The $a^{\dagger}$ bubble on the spherical surface $\mathcal{S}^2$ will thus transit topologically and the bit grids thus maintain the non-locality on the holographic horizon/ surface.

2. 6. THE QUANTUM BLACKHOLE HORIZON ENTROPY

So, now, by Landauer's principle, any logically irreversible process of manipulation of information should result in a corresponding increase of entropy in the information non-bearing degrees of freedom of the holographic system where the actual process is taking place. Consider therefore a stationary blackhole. On its horizon, we have

$$\Delta A\ \Delta n \geq \frac{G\hbar}{c^3} \tag{1}$$

Then,

$$\Delta A\ \Delta n \frac{c^3}{G} \geq \hbar \tag{39}$$

The gravitational energy, $E = \boldsymbol{F} \cdot \boldsymbol{R} = {}^{GM^2}/_{R}$. So,

$$\Delta A\ \Delta n \frac{M^2 c^4}{E\ c\ R} \geq \hbar \tag{56}$$

or

$$\Delta A\ \Delta n \frac{E^3}{EcR} \geq \hbar \tag{57}$$

Take $E^2 = E_{Pl}^2 = {c^5 \hbar}/{G}$ in the numerator above. Then we have

$$\Delta A\ \Delta n \frac{c^5 \hbar}{G} \frac{1}{E\ c\ R} \geq \hbar \tag{58}$$

or

$$\Delta A\ \Delta n \frac{c^3}{G\hbar} \frac{c}{R} \geq \frac{E}{\hbar} \tag{59}$$

$$\frac{c^3}{G\hbar}\ \Delta A \approx k_B \mathrm{T} \ell n 2 \tag{60}$$

Then, we have

$$\Delta A \frac{\Delta n}{c} \frac{E^3}{ER} \approx \hbar \tag{61}$$

For the horizon surface, $R = R_S = {2GM}/{c^2}$, the Schwarzschild radius. So,

$$\Delta A \frac{\Delta n}{c} E \frac{c^2}{2GM} \approx \hbar \tag{62}$$

$$\frac{1}{2} \Delta A\ \Delta n k_B \mathrm{T} \ell n 2\ \frac{c^3}{G\hbar} \approx Mc^2 \tag{63}$$

So, taking Mc^2 for all intents and purposes as ΔQ, the heat evolved in erasing an information bit.

$$\frac{1}{2} \Delta A\ \Delta n \frac{k_B c^3}{G\hbar}\ \ell n 2 \approx \frac{\Delta Q}{T} \tag{64}$$

Many interpretations are possible. For example, $\Delta n \cdot E$ is the total energy expended in the erasure of Δn bitson the horizon. Now, alternately from the above section 6, $\varphi = \pi n$ so take $\varphi = \frac{1}{\sqrt{3}\gamma}$ so that $n = {1}/{\pi\sqrt{3}\gamma}$ (where γ is the Immirzi parameter). Then,

$$\delta S \approx \frac{1}{2} \frac{k_B c^3}{G\hbar} \frac{1}{\pi\sqrt{3}} \frac{1}{\gamma} (\ell n 2) \delta \mathrm{A} \tag{65}$$

or, upon integrating we have

$$S_{BH} \approx \frac{1}{2} \frac{k_B c^3}{G\hbar} \frac{1}{\pi\sqrt{3}} \frac{1}{\gamma} (\ell n 2) A_{EH} \tag{66}$$

Taking $\gamma = {2\ell n 2}/{\pi\sqrt{3}}$, we have

$$S_{BH} = \frac{1}{4} \frac{k_B c^3}{G\hbar} A_{EH} \tag{67}$$

This is the Loop Quantum Gravity result for the calculation of the quantum horizon entropy. Now, we see that the exact Bekenstein-Hawking blackhole entropy relation comes through for the above choice of the Immirzi parameter. Let us dig a little deeper, viz.,

$$\Delta A \frac{\Delta n}{c} E \frac{c^2}{2GM} \approx \hbar \tag{68}$$

$$\frac{1}{2} \Delta A \Delta E \frac{c^3}{G\hbar} \approx M c^2 \tag{69}$$

$\frac{1}{2} \Delta A \, k_B \mathrm{T} \ell n 2 \, \frac{c^3}{G\hbar} \approx \Delta Q$, the heat evolved.

Therefore,

$$\frac{\Delta Q}{T} \approx \Delta S = \frac{1}{2} \frac{k_B c^3}{G\hbar} (\ell n 2) \Delta \mathrm{A} \tag{70}$$

or

$$S_{BH} = \frac{1}{2} \frac{k_B c^3}{G\hbar} A_{EH} (\ell n 2) \tag{71}$$

which we rewrite as

$$S_{BH} = \frac{1}{2} \frac{c^3}{G\hbar} A_{EH} (k_B \ell n 2) \tag{72}$$

So, it is clear that the correct formula is delivered when one takes the horizon distance from the *"blackhole center"* i.e., the correct physical or thermodynamic horizon radius as

$$R_{corr} = \frac{4GM}{c^2} \tag{73}$$

This is where lies the physical or information thermodynamic horizon or more righteously – the *holographic information geometric horizon*.

Then, the holographic uncertainty provides with the formula

$$S_{BH} = \frac{1}{4} (\ell n 2) A_{EH} \tag{74}$$

The $\ell n 2$ is not really directly a quantum correction but a Landauer's correction. Quantum geometry has nothing to do here.

However, what about the information bearing degrees of freedom just outside the horizon? There, the entropy will not have the logarithmic correction and in natural units,

$$S_{BH} = \frac{1}{4} A_{EH} \tag{75}$$

The surface for which the entropy just loses its logarithmic correction is the Bekenstein Horizon for, that is where the classical Bekenstein formula holds. This is the horizon correction discussed by the author [4] in the context of loop quantum gravity.

So apart from the holographic uncertainty and the inherent Planck scale dispersion of $\hat{A}$ and $\hat{n}$, there is no quantum gravity. Only theory is that of irreversible thermodynamics and the concomitant Landauer's Principle and the Landauer limit of lower bound on the energy expended in the thermodynamic erasure of a bit of information viz., $k_B T(\ell n 2)$.

Thus, in our endeavor to derive the blackhole entropy, we have stumbled upon the notion of a physical or thermodynamic horizon.

3. CONCLUSIONS

We have shown that an uncertainty more fundamental than the Heisenberg uncertainties exists – on the holographic boundary bounding the 3-space. This 3-space is the domain of ordinary non-relativistic quantum mechanics and hence of the Heisenberg uncertainty principle. The uncertainty we have derived or rather proved to exist on the holographic in nature and information- geometric in character. The Heisenberg uncertainties – all of them – follow from this fundamental uncertainty on the holographic surface if one simply takes the holographic surface to be spherical and bounding the quantum system held at its center. Then all's left is some set of simple algebraic manipulations. Next, we have demonstrated the quantum blackhole entropy formula with the logarithmic correction by simply adopting the Landauer principle for thermodynamic erasure of the information bit applied to the holographic uncertainty impressed on the blackhole horizon. In a bid to derive the quantum blackhole entropy the relevant horizon is found not to be the one defined by the Schwarzschild radius but rather to lie at a radius twice that of the Schwarzschild radius. The new horizon is the corrected or the physical horizon. We have dubbed this the *Holographic Information Geometric Horizon*.

The key idea is that if we derive the most general and fundamental relations which use a single fundamental compelling principle such as the holographic principle for their derivation and the relations strive to unify geometry and information – the prime endeavor of the holographic principle – in a combinatorial way or by bringing in combinatorial quantities, then the fundamental relations in the bulk of the manifold space bounded by the holographic surface, seem to be delivered by these holographic fundamental relations. Something like this has been demonstrated also in [3]. Something like this will genuinely make the physics much simpler and we should all come together to make such endeavors – to make physics as simple as possible.

Acknowledgement

The author wishes to thank Prof. Dr. Tomasz Borowski for his kind help and encouragement. He further wishes to thank Mr. Deepak Jaiaswal for technical assistance. He wishes to thank Prof. Dr. Michael E. Fisher, University of Maryland, for exposing him to the wonderful world of the Wilsonian Renormalization Group and the RG flows and the concomitant theory of the second order phase transitions and the renormalized Wilson-Fisher fixed point that corresponds to the peaked point in the lambda transition observed universally. Thanks are also due to Prof. Dr. Jeffrey D. Adams of the Math Department, University of Maryland, for teaching him some Lie groups and initiating him into the same. He also wishes to thank Prof. Dr. Graham Partis for his timely help and encouragement. Further, the author wishes to thank Prof. Prabhakar R. Hampiholi and the Chair of the Math Department Prof. Dr. Sudhir R. Jog, both of the Gogte Institute of Technology (GIT, Belgaum). To, Prof. Dr. Ravi S. Kulkarni (Professor of Mathematics, Bhaskaracharya Prathisthana, Pune, President of DST-NBHM and President of the Ramanujan Mathematical Society) for teaching him some extra fresh perspectives on geometry leading to Topological Dynamics. To Prof. Dr. A. K. Nandakumaran (Professor of Mathematics, IISc, Bangalore) are due thanks for teaching the author a complete course on Theory of Ordinary and Partial Differential Equations in a crash course. Finally, he wishes to thank his invaluable parents, Mrs. Supriya (Mamta) Ajit Kabe and Mr. Ajit Mangeshrao Kabe, for their undying love support and encouragement and their patience. Last but not the least, the author wishes to thank Prof. Dr. T. Padmanabhan for his wonderful pedagogical works in the form of such beautiful and lucidly readable books and papers, a few of these gems being cited here in the references.

Biography

Koustubh Kabe is Dr. Phil (PhD) / Sc.D. in Theoretical Physics. He has published several research papers investigating into the foundational issues of gravitational physics and the understanding of time and quantum gravity. He is also working on the problem of gravity and the cosmological implications in the framework of string theory. He is currently studying Quantum Measurement in addition to all of the above. His research interests are in the fields of General Theoretical Physics, Physical Mathematics, Theoretical Astrophysics, Theoretical High-energy Physics, Modern Theoretical Physics, Physical Cosmology, Geometric Analysis, Number Theory, Algebraic Geometry and lastly, Philosophy, Epistemology and Pedagogy behind Physical Theories. He is an author of a book titled "*Blackhole Dynamic Potentials and Condensed Geometry: New Perspectives on Blackhole Dynamics and Modern Canonical Quantum General Relativity*".

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(Received 25 May 2016; accepted 14 June 2016)