A Solution to Black Hole Information Paradox

Olayode Olalekan Babatunde

Abstract

We present a unified theoretical framework that connects black holes, dark matter, and dark energy through quantum gravity. By hypothesizing that the speed of light is quantized, we show that particles at the event horizon can reach velocities up to twice the speed of light, leading to significant increases in energy. This mechanism allows a spin-zero particle to decay into an electron–positron pair and Extending this framework, we demonstrated that photons can also reach energies at which they become unstable and decay into spin-half particle–antiparticle pairs. We relate the stress-energy scalar tensor to discrete speeds and demonstrate that the vacuum expectation value of the cosmological constant determines the energy scale of these processes. Electric charge is defined in terms of occupation number and azimuthal quantum number, naturally yielding neutral spin-zero states and charged spin-half states. We further explore entropy and area relationships at the event horizon, showing that entanglement entropy exhibits logarithmic growth for early-time radiation and decreases at late times, consistent with the Page curve. Finally, we discuss particle annihilation within the horizon which nullify the existence of Hawking radiation. This framework provides a potential bridge between general relativity and quantum mechanics, offering new insights into black hole thermodynamics and quantum gravity phenomenology.

1.0 Introduction

Stephen Hawking demonstrated that black holes emit radiation due to quantum effect near the event horizon a phenomenon now called Hawking radiation[1], this discovery shows that black holes emit energy similarly to a black body. However, this phenomenon appears to violate a core principle of quantum mechanics that information cannot be destroyed.

This literature focuses on the nature of black holes' event horizon and the role of quantum entanglement in the context of black hole information paradox [2-4,12, 8-11]. Specifically, it explores Bekenstein-Hawking entropy [5, 6] and entanglement entropy which can be demonstrated by using strong subadditive of quantum entropy [19-21] and monogamy of entanglement [13-15]. The Page curve describes the time evolution of black hole entanglement entropy, spanning from early-time radiation to late-time radiation [22-24]. We believe that a deeper investigation and analysis of the Page curve may provide valuable insights and help unravel the mystery behind the black hole information paradox.

1.1 Theoretical frame work

The framework proposed in this article builds on these concepts, suggesting that black holes, dark matter, and dark energy can be understood within a single unified theory of quantum gravity.

The original EPR paradox [28,29] used position and momentum as the entangled variables. However, it was in Bohm's work [25-27] that the use of a spin-zero particle was first adopted. In a similar vein, we consider the following scenario:

Suppose a spin-zero particle at the event horizon of a black hole decays into an electron–positron pair, with one particle heading inward and the other heading outward. What is the fate of the incoming and outgoing particles?

Hypothesis below is fundamental statement or assumption that is considered to be true without proof, often because it is based on empirical evidence and is necessary assumptions for the theoretical framework [7].

Hypothesis : "The speed of light is quantized"

This hypothesis suggests that the speed of light is not continuous, but rather quantized, meaning it comes in discrete packets or quanta. This idea challenges our classical understanding of light propagation and has implications for our understanding of the

behavior of particles at the quantum level. We show speed is related to the scalar stress-energy tensor or Ricci scalar curvature tensor in appendix A.

2.0 Mathematical Formulation

The theory introduces a mathematical framework that relates the stress-energy scalar tensor to discrete speed and specifically two speeds of light:

$$T^2 = 1 - \chi \qquad (1)$$

Where χ is Euler characteristics showing that the stress-energy scalar tensor is related to discrete speed and specifically two speeds of light.

Moreover, we argue that velocity is an inherent property of space-time curvature. At velocities approaching twice the speed of light, the Ricci curvature could exhibit quadratic behavior. A more details in appendix A.

$\langle \Lambda^2 \rangle$ represent the vacuum expected value of dark energy or cosmological constant and n represents the number of particles in particle states, before the particle decays $n = 1$ and after the particle decays $n = 2$.

$$\langle \Lambda^2 \rangle = \pm \frac{2}{3} n^2 MeV \qquad (2)$$

The vacuum expectation value of cosmological constant determines the energy scale. Before the spin zero particle decays the energy scale is 0.666MeV and after the it decays into electro-positron pair the energy scale becomes 2.666MeV

2.1 Event horizon and entanglement entropy

$$A = 2n\pi R^2 = \Lambda^2 \qquad (3)$$

(3) shows a relationship between area of event horizon and vacuum expected value of cosmological constant.

$$S = \frac{A}{2n} \qquad (4)$$

The work of Stephen hawking and Bekenstein provide a fascinating and direct connection between area and entropy of events horizon of a black hole [1,5]. In this article (4) is written in the similar spirit.

Now let us consider the spin correlation conditions: if the spin of the particles such as electron-positron pair and spin half positive photon and it anti particle are the same then

$p - q = 0$ otherwise $p + q = 1$. Event horizon entropy is defined as $S = \pi T^2$, $where\ T^2 = pq$.

$$\frac{T^2 x^2}{2} = p + q \qquad (5)$$

2.2 Gravitational potential energy and early-time radiation

$$w(t) = \int_0^{\infty} x e^x\ t^{-x} = \left(\frac{1}{1-t}\right) x \qquad (6)$$

(6) is Laplace transformation over interval [0, ∞) where $t\ is\ time,$ At $t = 0, w(0) = x$

$$\Phi(x) = \Lambda^2 + w(t) \qquad (7)$$

Gravitational potential energy combines square of cosmological constant and work function (7).

Cosmological constant acts like kinetic energy in (7) which accelerate particles at the event horizon. The result in (3) shows relationship between area of event horizon, cosmological constant and square of Ricci scalar curvature. This suggest that cosmological constant will accelerate particles velocities up to twice the speed of light in vacuum. Under such extreme conditions, the energy of a spin-zero particle will increase significantly, and potentially up to twice of its initial energy. This increase in energy will render the particle unstable, leading to its decay into an electron-positron pair.

Given the well-established empirical energy of electron-positron pair ($\sim 1MeV\ each$), one can, in principle, estimate the original energy of the spin-zero particle prior to decay. We propose that the initial energy of this spin-zero particle is approximately equal to the electron energy $(0.521MeV)$.

Extending this reasoning to photons, we hypothesize that at the event horizon, the cosmological constant will accelerate a photon to twice of its initial energy, effectively reaching $(\sim 2MeV)$. At this energy, the photon will become unstable and decay into a spin-half particle and its corresponding antiparticle.

$w(t) = \left(\frac{1}{1-t}\right) n$ workfunction describes work done by gravity to move particles beyond the event horizon of black holes.

Regarding electric charge, let, n represent the number of particles in a given quantum state. We define the azimuthal quantum number as $l = n - 1$ Accordingly, the charge associated

with each ground state can be expressed as $Q = \pm l$. For a single particle $n = 1$ then $l = 0$ resulting in $Q = 0$ and also for the two particles $n = 2, l = 1$, yielding charges of $Q = \pm 1$ thus, a spin-half photon could carry a charge of $Q = +1$ with its antiparticle carrying $Q = -1$ while the spin-zero particle remains neutral with $Q = 0$.

$$\Delta s = 2\ln(n) - \ln(2) = \ln(\mathrm{p}) + \ln(q) - \ln(pq) \quad (8)$$

For n greater or equal to two as shown in (8), we claim that early times radiation exhibits logarithmic growth, this implies a slow release of information from the black hole and as the number of particle increases the entanglement entropy increases. This is in agreement with page curve [18].

2.3 Evolution of entanglement entropy at late times radiation

At late time the entanglement entropy which measures the degree of entanglement between particle inside the event horizon and its anti particle outside the event horizon of black holes approaches zero which is in agreement with page curve [18]. So the particle inside the event horizon are disentangle with those outside it

If we consider a particle and its anti-particle such as electro-positron pair is drop from a Gravitational potential within the event horizon.

Firstly, the intense gravitational field of the black hole, as described by General Relativity, causes matter's gravitational effect to curve spacetime such that all future-oriented geodesics inside black hole's event horizon point toward the singularity. Consequently, both the particle and the antiparticle will follow these geodesics, accelerating towards the singularity.

As they descend, the gravitational gradient, or tidal force, will become increasingly significant, leading to spaghettification.

On the contrary we can give better explanation within framework of this article, as time approaches infinity, the workfunction vanishes (6). the gravitational potential energy of a particle-antiparticle pair (like an electron-positron pair, spin-half photon and its antiparticle) within a black hole's event horizon is converted into cosmological constant (dark energy) $\Phi(x) = \Lambda^2$, causing them to accelerate towards each other at two speed of light and annihilate, Consequentially, electro-positron pair is annihilated then two neutral spin-zero electron-like particles are released within event horizon as shown below.

$$e^+ + e^- \rightarrow 2e^0 \quad (9)$$

Also positive spin-half photon and its antiparticle annihilated and released two photons as shown below.

$$\gamma^{+} + \gamma^{-} \rightarrow 2\gamma \qquad (10)$$

concerning hawking radiation if a negative-energy virtual electron at late times annihilate with its antiparticle behind the event horizon according to this framework there will be no hawking radiation.

- **Experimental discovery of spin-half photon and spin-zero electron-like particle**

This article predict the existence of positive and negative spin-half photons and spin-zero electron-like particles though we don't put forward how this particles can be discovered experimentally.

3.0 Conclusion

In this work, we have shown how a quantized speed of light and a cosmological constant driven acceleration mechanism can lead to novel particle decay channels at black hole event horizons. By establishing a connection between event horizon area, speed of light, and the cosmological constant, we develop a framework that links geometry, quantum fields, and thermodynamics, providing a potential bridge between general relativity and quantum mechanics.

Our analysis predicts the existence of spin-zero particles with energy comparable to the electron and spin-half photons which are likely dark matter candidates. We also studied the Page curve, showing that at late times, annihilation processes such as electron–positron pairs, spin-half photons and their antiparticles, and even virtual electron–positron pairs. These processes may effectively nullify the existence of Hawking radiation.

Furthermore, we proposed a mechanism in which the cosmological constant induces acceleration of particles at black hole event horizon. Under such conditions, a spin-zero particle can acquire sufficient energy for its energy to increase, leading to decay into an electron-positron pair. Extending this framework, we demonstrated that photons can also reach energies at which they become unstable and decay into spin-half particle–antiparticle pair. We explored the relationship between velocity, space-time curvature, and gravitational potential energy, and proposed a charge assignment based on

occupation number and azimuthal quantum number. This approach provides a potential link between dark energy, particle physics, and black hole thermodynamics.

These results open new avenues for exploring quantum gravity phenomenology and motivate further theoretical and experimental investigations into particle behavior in strong gravitational fields.

Appendix A: Quantization of The Speed of Light in Terms of Stress-Energy Scalar Tensor and Ricci Scalar Curvature

$$T^2 = 1 - \chi \qquad (A1)$$

Binomial approximation of scalar stress-energy tensor $T^2 = 1 + nx$ where $n = \frac{v}{c}$ is velocity and c is the speed of light. At $x = -1, T^n = 1 - n$ when the velocity is equal to one of light $T^1 = 0$ and at two speed of light it becomes $T^2 = 3\ for\ torus\ and\ T^2 = -1\ for\ sphere$. Where x is Euler characteristics and It shows that stress-energy scalar tensor is related to discrete speed and specifically two speed of light.

$$R\mu\nu - \frac{1}{2}Rg\mu\nu = 0 \qquad (A2)$$

$$R\mu\nu R^{\mu\nu} = 1 - \frac{1}{4}R^2 g\mu\nu g^{\mu\nu} \qquad (A3)$$

$$R\mu\nu - \frac{1}{2}g\mu\nu = 1 \qquad (A4)$$

$$R\mu\nu R^{\mu\nu} = \frac{1}{4}g\mu\nu g^{\mu\nu} \qquad (A5)$$

$$R^2 = 3 \qquad (A6)$$

(A2) is the vacuum solution of Einstein's Ricci curvature tensor, if put together (A2) and (A4) we will arrive at (A5) which is value of second order in Ricci scalar curvature. We will observe that the value we get from second order in stress-energy scalar tensor for torus in (A1) is the same as the value of second order in Ricci scalar curvature in (A6), So they are interchangeable.

Appendix B: Vacuum Expectation Value and Gauge Invariance

$\langle \Lambda^2 \rangle$ represents the vacuum expected value of dark energy or cosmological constant and n represents the number of particles in a states, before the particle decays $n = 1$ and after the particle decays $n = 2$ Special orthogonal group SO(2) implies that $\det(A)^2 = \pm 1$ so,

$$\langle n|det(A)^2|n\rangle = \langle \Lambda^2 \rangle = \langle AA^T \rangle \qquad (B1)$$

$$\langle \Lambda^2 \rangle = \pm \frac{2}{3} n^2 Mev \qquad (B2)$$

$$R^2 = \frac{\Lambda^2}{2n\pi\Phi} A\mu A^\mu \qquad (B3)$$

$$R^2 = \frac{\Lambda^2}{2n\pi\Phi} J\mu J^\mu \qquad (B4)$$

$$\frac{1}{\Phi} A\mu A^\mu + \nabla^2 \Phi = \frac{1}{\Phi} A'\mu A'^\mu \qquad (B4)$$

$$\frac{1}{\Phi} J\mu J^\mu + \nabla^2 \Phi = \frac{1}{\Phi} J'\mu J'^\mu \qquad (B5)$$

$$\nabla^2 \Phi = 0 \qquad (B6)$$

(B4) and (B5) relate electromagnetic potential $A\mu$ and electromagnetic potential to gravitational potential energy Φ in such a way that is gauge invariance.

$$\frac{A'\mu A'^\mu}{\Phi} = 1 \qquad (B7)$$

$$\frac{J'\mu J'^\mu}{\Phi} = 1 \qquad (B8)$$

The laplacian $\nabla^2 \Phi = 0$ implies that the right hand side and left hand side of (B4) and (B5) are equal is a crucial aspect of the theory. Now if we go back to (B4) and (B5) we will realize the connection between cosmological constant Ricci scalar curvature.

Appendix C: Taylor Expansion of Differential Equation

$$T\frac{\partial^2}{\partial x^2}\ \psi(x) = T^2\psi(x) \qquad (C1)$$

Using the Taylor series expansion, we can solve (C1) around $x = 0$. Assuming $\psi(x)$ is analytic at $x = 0$. $\frac{\partial^2}{\partial x^2}$ is the second derivative with respect to position (x)

$\psi(x)$ is the wave function or displacement and T represents scalar Stress-Energy tensor and Stress-Energy scalar tensor represents the spring constant or stiffness .

$$\psi(x) = \psi(0) - \frac{x^2T^2}{2}\psi(0) + \cdots \qquad (C2)$$

Taylor approximation of wave function shows that gravitational potential energy $\Phi(x) = \frac{T^2x^2}{2}$ this can be related to the as shown in (C3).

Now$p = p1e1 + p2e2 + p3e3$represents momentum-probability state and $q = q1e1 + q2e2 + q3e3$ also represents momentum-probability state of its anti particle. Where $e = e1 + e2 + e3 + \cdots + en$ is Clifford algebra bases and we can relate it to Pauli matrices to describe entanglement of black hole such as $p + q = \sigma1(p1 + q1) + \sigma2(p2 + q2) + \cdots + \sigma n(pn + qn)$. σn Is Pauli matrices though we are only interested in the x-axis direction. Now let us consider the spin correlation conditions: if the spin of the particles such as electron-positron pairs and spin half positive photon and it anti particle are the same then $p - q = 0$ otherwise $p + q = 1$

If we substitute $T^2 = pq$ Then we can express the spin probability condition in terms of gravitational potential energy as shown in (C3).

$$\frac{x^2}{2} = \frac{p+q}{pq} \qquad (C3)$$

Acknowledgment

The mighty hand that writes beautiful equations that only a feeble mind will understand; hallowed be thy name.

I would like to extend my deepest gratitude to the individuals who has made this research possible.

To my parents, I express my heartfelt appreciation to their unwavering, support, guidance and encouragement throughout my academic journey. Your moral, financial and emotional contributions have been invaluable.

Additionally, I am grateful to my siblings, Taiwo, wuraola, aunty jumoke and kehinde. I also aunty Asiyah Arisekola Alao for her paying for the publication of my research work.

Thank you all for being integral part of my Journey.

I would like to extend my gratitude to the following institutions for making high quality physics video lectures available online:

- Perimeter Institute for Theoretical Physics
- Massachusetts Institute of Technology
- National program on technology enhanced learning
- Abdu Salam international center for theoretical physics
- Stanford University
- Yale University

Just to mention a few, I also appreciate the effort of physics popularizes who have made complex concept understandable to the broader audience and individuals who has shared their knowledge of physics and math through their various YouTube channels including

- Dr. Brian Greene
- Dr. Sabine Hossenfelder
- Dr. Don Lincoln
- Dr. Michio Kaku
- Dr. PhysicsA (Bon Eagle)
- Dr. Anwar Sabieh
- Dr. N. J. Wildberger
- Dr. Frederick Schuller (FAU)
- Phillip Gibbs (creator of vixra)

Your collective efforts have democratized access to physics education and inspire a new generation of physicist and science enthusiast and lastly I want to thank Prof. George Pullin for his constructive criticism.

REFERENCES

[1] Hawking Stephen (2005) “information loss in black holes” arXiv: 1306.0533

[2] Susskind, L; L Thorlacius, L; Uglum, J. “The stretch horizon and black Holes complementary “ arXiv: hep-th/9306069

[3] Maldacena, J; Susskind, L. “ Cool horizon for entangled black holes “ arXiv: 1306.0533

[4] Almheiri, Ahed; Marolf, Donald; Polchinski, Joseph ; Sully, James (2013) . arXiv : 1207.3125

[5] Strominger, A; Vafa, C (1996). “Microscopic origin of Bekeinstein-Hawking entropy “ arXiv: hep-th/9601029

[6] Maldacena, Juan(1990). “The large N limit of super conformal theories and super gravity. arXiv: hep-th/9711200

[7] Babatunde, O,O (2023) “A solution to black hole information paradox “ . Journal of modern applied physics, 3.

[8] S. D. Mathur, "The fuzzball proposal for black holes: An elementary review," Fortsch. Phys. 53, 793 (2005) arXiv:hep-th/0502057 hep-th.

[9] S. D. Mathur, "The quantum structure of black holes," Class. Quant. Grav. 23, R115 (2006) arXiv:hep-th/0510180 hep-th.

[10] S. Giusto, O. Lunin, S. D. Mathur and D. Turton, "D1-D5-P microstates at the cap," JHEP 1302, 050 (2013) arXiv:1211.0306 hep-th.

[11] I. Bena and N. P. Warner, "Resolving the Structure of Black Holes: Philosophizing with a Hammer," arXiv:1311.4538/hep-th.

[12] K. Papadodimas and S. Raju, "An Infalling Observer in AdS/CFT" arXiv:1211.6767/hep-th.

[13] Coffman, Valerie; Kundu, Joydip; Wootters, William (2000). "Distributed entanglement"arXiv: 9907047/quant-ph.

[14] Osborne, Tobias J.; Verstraete, Frank (2006). "General Monogamy Inequality for Bipartite Qubit Entanglement" arXiv :0502176/hep-th.

[15] Seevnick, Michael (2010) “ Monogamy of correlations versus monogamy oo entanglement” : arXiv : 0908.1867.

[16] Brügmann, Bernd; Gambini, Rodolfo; Pullin, Jorge (1992), "Jones Polynomials for Intersecting Knots as Physical States of Quantum Gravity", arXiv: hep-th/9202018.

[17] Brügmann, Bernd; Gambini, Rodolfo; Pullin, Jorge (1993), "How the Jones polynomial gives rise to physical states of quantum general relativity", arXiv : 9203040/hep-th.

[18] Page, Don N. (6 December 1993). "Information in Black Hole Radiation" arXiv :936083/hep-th.

[19] Carlen, Eric A.; Lieb, Elliott H. (2012). "Bounds for Entanglement via an Extension of Strong Subadditivity of Entropy". arXiv: 1203.4719

[20] Araki, Huzihiro; Lieb, Elliott H. (1970). "Entropy inequalities". Communications in Mathematical Physics. 18 (2): 160–170.

[21] Lieb, Elliott H.; Ruskai, Mary Beth (1973) "Proof of the strong subadditivity of quantum-mechanical entropy". Journal of Mathematical Physics. 14 (12). AIP Publishing: 1938–1941.

[22] Stefan kehrein "page curve entanglement dynamic in a analytically solvable model" arxiv : 2311.18045

[23] Tomagohn Ray, Abhishek Dhar, Manas kulkarni "page curve like dynamics in interacting quantum systems” arXiv: 2504.14675

[24] Jonas Glatthard "page-curve-like entanglement dynamics in open quantum systems" arXiv: 2401.06042

[25] Bohm, D. (1951). *Quantum Theory*, Prentice-Hall, Englewood Cliffs, pp. 614-619.

[26] Bohm, D., & Aharonov, Y. (1957). Physical Review, 108, 1070-1076.

[27] Mermin, N. D. (1993). Reviews of Modern Physics, 65, 803-8.

[28] Einstein, A.; Rosen, N. “The Particle Problem in the General Theory of Relativity”. Physical Review. 48, 73(1935).

[29] A. Einstein, B Podoski and A. Rosen, “Can quantum mechanical description of physical reality be considered complete?,” Phys. Rev 47.777 (1935).