Scientific Research Publishing

Journal of Modern Physics, 2024, 15, 938-949
https://www.scirp.org/journal/jmp
ISSN Online: 2153-120X
ISSN Print: 2153-1196

Quantum Unruh Effect on Radiation of Black Holes

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How to cite this paper: Zhang, T.X. (2024) Quantum Unruh Effect on Radiation of Black Holes. *Journal of Modern Physics*, **15**, 938-949.
https://doi.org/10.4236/jmp.2024.156039

Received: April 3, 2024
Accepted: May 25, 2024
Published: May 28, 2024

Abstract

The quantum Unruh effect on radiation of a gravitational object including a black hole is analyzed and calculated. It is surprisingly found that the well-known Hawking radiation of a black hole is not physical. Applying the Stephan-Boltzmann law with the use of the Unruh radiation temperature at the surface of a black hole to calculate the power of radiation of the black hole is conceptually unphysical. This is because the Unruh radiation temperature results from the gravitational field of the object rather than from the thermal motion of matter of the object, so that the Stephan-Boltzmann law is not applicable. This paper shows that the emission power of Unruh radiation from a gravitational object should be calculated in terms of the rate of increase of the total Unruh radiation energy outside the object. The result obtained from this study indicates that a gravitational object can emit Unruh radiation when the variation of its mass and radius satisfies an inequality of $\mathrm{d}M/M > 1.25\mathrm{d}R/R$. For a black hole, the emission of Unruh radiation does not occur unless it can loose its mass ($\mathrm{d}M < 0$). The emission power of Unruh radiation is only an extremely tiny part of the rate of mass-energy loss if the black hole is not extremely micro-sized. This study turns down our traditional understanding of the Hawking radiation and thermodynamics of black holes.

Keywords

Black Hole, Gravitation, Quantum Field Theory, Blackbody Radiation

1. Introduction

A black hole is an object, from which even light cannot escape due to its strong gravitational field. The existence of black holes in nature was theoretically predicted from the Schwarzschild solution of Einstein's general relativity a century ago [1] [2] and was confirmed recently from the observational detections of gravitational waves by the Laser Interferometer Gravitational Wave Observatory (LIGO) [3]. A star with mass above around twenty solar masses, when it runs out of its nuclear fuel, will end as a star-like black hole through a supernova explosion. Within each galaxy, in addition to the millions to billions of star-like black holes, there is usually a massive black hole with millions of solar masses at its center. The observed extremely luminous quasi-stellar objects, quasars, are run or powered by supermassive black holes with billions of solar masses. The observed highly energetic events, gamma-ray bursts, are believed to be generated or created when giant stars collapse into black holes or when two or more black holes including neutron stars merge. Our universe itself is an extremely supermassive and fully expanded black hole according to the author's well-developed black hole model of the universe [4] [5].

The inside of a black hole is a mystery, though it is generally believed that matter inside or once entering a black hole will gravitationally fall into the center and form a dreaded point-like or size-less singularity, where the matter density, pressure, and temperature go to infinity and the spacetime breaks down with infinite curvature [6]. The standard Big Bang model of the universe suggested that the universe originated from a Big Bang singularity [7]. Recently, the author of this paper has shown that, with the quantum Unruh effect, such dreaded size-less singularity cannot be actually formed because the total Unruh radiation energy of a size-less singularity goes to infinity and hence violates the law of energy conservation [8]. The formed singularity sphere has a finite radius, which is proportional to the square root of mass and extremely small in comparison with the size of the black hole. A size-less singularity cannot be formed unless it is also massless. In the black hole model of the universe, a black hole is hierarchically structured with infinite layers and the singularity is asymptotical with infinite singular subspacetimes [9].

Using the Unruh radiation temperature at the surface as the temperature of a black hole, Hawking [10] [11], in terms of the Stephan-Boltzmann law, obtained the radiation power of the black hole to be inversely proportional to the mass of the black hole. He further derived the evaporation time and entropy of the black hole, respectively, by setting the power of the Hawking radiation to be the rates of the mass-energy loss and heat transfer. The evaporation time is inversely proportional to the cube of the black hole mass, while the entropy is proportional to the square of the black hole radius or mass (*i.e.* proportional to the surface area of the black hole). However, the Unruh radiation temperature results from the gravitational field of the object rather than from the thermal motion of matter of the object. The Stephan-Boltzmann law describes the intensity of the thermal radiation emitted by matter in terms of that matter's temperature. Therefore, it is conceptually unphysical to apply the Stephan-Boltzmann law with the use of the Unruh radiation temperature at the surface of a black hole to calculate the power of radiation of the black hole. This non-applicability of the Stephan-Boltzmann law surprisingly leads to that the well-known Hawking radiation of a black hole is not physical.

The objective of this study is to investigate the quantum Unruh effect on radiation of gravitational objects including black holes. In Section 2, we first describe the quantum Unruh effect. Then, for a gravitational object, we explain how the Unruh radiation temperature and energy density distribute radially around the gravitational object. We further show how to calculate the total Unruh radiation energy outside the gravitational object. In Section 3, we calculate the emission power of the Unruh radiation of a gravitational object according to the rate of increase of the total Unruh radiation energy outside the gravitational object, including a black hole. For an effective comparison, we, in Section 4, briefly review how the Hawking radiation of a black hole is theorized based on the Unruh radiation temperature and Stephan-Boltzmann law. This study shows that a gravitational object can emit Unruh radiation conditionally depending on the variation of its mass and radius (or the variation of its gravitational field). For a black hole, the emission of Unruh radiation does not occur unless it can loose its mass. The emission power of Unruh radiation is only an extremely tiny part of the rate of mass-energy loss. The Stephan-Boltzmann law is not applicable to the Unruh radiation as the Unruh radiation temperature results from the gravitational field rather than from the matter's thermal motion.

2. The Quantum Unruh Effect and Radiation

The Unruh effect (also known as the Fulling-Davies-Unruh effect) is a strange, surprising prediction of quantum field theory [12] [13] [14]. It refers to that an accelerating observer detects a thermal radiation or thermal bath with temperature being proportional to the acceleration of the observer, expressed by [15] [16]

$$T = \frac{\hbar a}{2\pi c k_B}, \tag{1}$$

where $\hbar = h/2\pi$ with h the Planck constant, c is the speed of light in the free space, k_B is the Boltzmann constant, and a is the acceleration of the observer. A non-accelerating observer, however, does not detect such radiation. As it is a quantum phenomenon, the author prefers to call it as the quantum Unruh effect.

From Mach's principle of equivalence, gravitation and acceleration are equivalent. An object cannot recognize itself whether attracted by a gravitational force or in an accelerating system. Therefore, with Mach's principle of equivalence, the Unruh radiation temperature that an observer detects in a gravitational field will be [8]

$$T = \frac{\hbar g}{2\pi c k_B}, \tag{2}$$

where g is the gravitational acceleration or field. Here, to obtain Equation (2), we have simply replaced the acceleration a in Equation (1) by the gravitational acceleration g. This implies that an observer at rest in a gravitational field detects the Unruh radiation with temperature to be proportional to the gravitational acceleration. The physics of Unruh radiation is quantum field theory. In a gravitational field, the Unruh radiation temperature is proportional to the gravitational field, independent of the thermal heat of the local matter.

For a gravitational object with mass M and radius R, the magnitude of the gravitational acceleration g at a radial distance r is, according to the Newtonian gravitational law, given by

$$g(r) = \frac{GM}{r^2}, \tag{3}$$

where G is the gravitational constant. Then, by substituting Equation (3) into Equation (2), the Unruh radiation temperature of a gravitational object, in the Newtonian approximation, is obtained to be proportional to the mass and inversely proportional to the square of radial distance [8],

$$T(r) = \frac{\hbar G}{2\pi c k_B} \cdot \frac{M}{r^2}, \tag{4}$$

and the Unruh radiation energy density, in terms of Planck's law of blackbody radiation [17], is obtained to be proportional to the fourth power of mass and inversely proportional to the eighth power of radial distance [8],

$$u_\gamma(r) = \frac{\hbar G^4}{240\pi^2 c^7} \cdot \frac{M^4}{r^8}. \tag{5}$$

These results indicate that most of the Unruh radiation energy distributes in the space very nearly around the surface of the gravitational object (**Figure 1**).

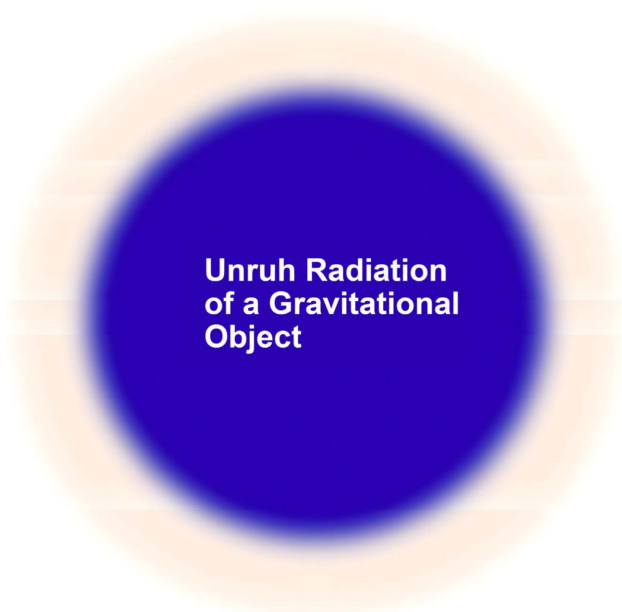

Figure 1. A schematic diagram sketches the Unruh radiation of a gravitational object. In this author's created sketch, the blue sphere is the gravitational object, while the light yellow spherical shell that surrounds the object is the Unruh radiation. It is gravitationally confined and distributes very nearly around the object without propagating to the outer space. The Unruh radiation energy density radially decreases by inversely proportional to the eighth power of the radial distance.

The Unruh radiation spreads radially, but the temperature and especially the energy density rapidly decrease with the radial distance. The radial distributions of Unruh radiation temperature and energy density are quite different from the blackbody radiation of thermal matter, which gives the radiation temperature equal to the matter's temperature at the surface of blackbody and the radiation energy density and flux to be inversely proportional to the square of radial distance. The Unruh radiation of a static gravitational object is gravitationally confined and unable to propagate radially outward to the outer space while the radiation of a normal blackbody does.

Recently, from the volume integration of the radiation energy density Equation (5) in the whole space outside a gravitational object, Zhang [8] obtained the total Unruh radiation energy of the gravitational object as,

$$U_\gamma = \int_R^\infty u_\gamma(r) 4\pi r^2 \mathrm{d}r = \frac{\hbar G^4}{300\pi c^7} \cdot \frac{M^4}{R^5} = \alpha \frac{M^4}{R^5}, \tag{6}$$

which is proportional to the fourth power of the mass and inversely proportional to the fifth power of the radius. An object, if it is more massive and more compact (or has a stronger gravitational field), has more Unruh radiation energy surrounded. A typical stellar star, neutron star, star-like black hole, or supermassive black hole surrounds Unruh radiation with total energy about 10^{-60}, 10^{-37}, 10^{-34}, or 10^{-43} J, respectively. All these values are extremely small and give negligible contributions to the universe.

If the gravitational object is static (or its gravitational field is not varied), e.g. does neither gain mass ($\mathrm{d}M = 0$) nor shrink size ($\mathrm{d}R = 0$), the Unruh radiation of the object will be also static, neither changing the spatial distributions of the Unruh radiation temperature and energy density nor varying the total Unruh radiation energy that surrounds the gravitational object ($\mathrm{d}U_\gamma = 0$). That is, a static gravitational object does not emit Unruh radiation. If the gravitational object is dynamic (or its gravitational field is varied), e.g. either gains mass ($\mathrm{d}M > 0$) or shrinks size ($\mathrm{d}R < 0$), the Unruh radiation of the object will be also dynamic, changing the spatial distributions of the Unruh radiation temperature and energy density and increasing the total Unruh radiation energy that surrounds the gravitational object ($\mathrm{d}U_\gamma > 0$). In this case, the gravitational object emits Unruh radiation.

3. The Power of the Unruh Radiation

The power of the Unruh radiation of a gravitational object can be calculated according to the rate of change of the total Unruh radiation energy [8]. That is, the time derivative of Equation (6) gives the power as,

$$P_\gamma = \frac{\mathrm{d}U_\gamma}{\mathrm{d}t} = \alpha \frac{4M^3}{R^5}\frac{\mathrm{d}M}{\mathrm{d}t} - \alpha \frac{5M^4}{R^6}\frac{\mathrm{d}R}{\mathrm{d}t} = \alpha \frac{M^4}{R^5}\left(\frac{4}{M}\frac{\mathrm{d}M}{\mathrm{d}t} - \frac{5}{R}\frac{\mathrm{d}R}{\mathrm{d}t}\right). \tag{7}$$

For the gravitational object to emit Unruh radiation, we need the power or the time rate of change of the total Unruh radiation energy to be positive ($P_\gamma > 0$), *i.e.*

the rates of changes in relative mass and radius satisfy the following inequality,

$$\frac{1}{M}\frac{\mathrm{d}M}{\mathrm{d}t} > \frac{5}{4R}\frac{\mathrm{d}R}{\mathrm{d}t} \quad \text{or} \quad \frac{\mathrm{d}M}{M} > \frac{5}{4}\frac{\mathrm{d}R}{R}. \tag{8}$$

That is, if the rate of change of its relative mass is 1.25 times greater than the rate of change of its relative radius, the gravitational object emits Unruh radiation. Typically, a gravitationally collapsing object can emit Unruh radiation. A gravitationally matter-accreting object can emit Unruh radiation when the changes of its mass and radius satisfy $\mathrm{d}M/M > 1.25\mathrm{d}R/R$.

For example, considering a neutron star with mass of 1.5 solar masses and radius of 20 km, we can obtain the Unruh radiation temperature at its surface to be about 4.06×10^{-9} K, many orders in magnitude lower than the neutron star's actual matter temperature at the surface, and the total Unruh radiation energy outside the neutron star to be about 2.56×10^{-37} J, many orders in magnitude lower than the energy of a single photon of visible light. When the neutron star accretes 30% mass in one million years and meantime raises its radius by 10% (or $\mathrm{d}M/M = 3\mathrm{d}R/R$), it radiates the Unruh radiation energy of about 1.98×10^{-37} J with the emission power of Unruh radiation to be about 6.28×10^{-51} W. The neutron star decreases its gravitational potential energy by about 9.66×10^{45} J. The Unruh radiation energy is just a tiny part of its gravitational potential energy loss. If the neutron star remains static, *i.e.* does neither accrete matter nor vary its size, it does not radiate the Unruh radiation.

For a black hole, we have the total Unruh radiation energy to be inversely proportional to the mass of the black hole [8],

$$U_\gamma = \alpha\frac{M^4}{R^5} = \frac{\hbar G^4}{300\pi c^7}\cdot\left(\frac{c^2}{2G}\right)^5\frac{1}{M} = \frac{\hbar c^3}{9600\pi GM}. \tag{9}$$

Here, we have used the mass-radius relation of a black hole,

$$\frac{2GM}{c^2R} = 1. \tag{10}$$

For a star-like black hole with 3 solar masses, we have the total Unruh radiation energy to be $U_\gamma \sim 2.35 \times 10^{-34}$ J. For a supermassive black hole with one billion solar masses, we have $U_\gamma \sim 7.05 \times 10^{-43}$ J. These results indicate that the contributions of Unruh radiation from all of the star-like, massive, and supermassive black holes to the universe are also negligible. The smaller a black hole is, the larger its total Unruh radiation energy is.

Taking a derivative of Equation (9) with respect to time, we have the rate of change of the total Unruh radiation energy that surrounds the black hole as,

$$P_\gamma = \frac{\mathrm{d}U_\gamma}{\mathrm{d}t} = -\frac{\hbar c^3}{9600\pi GM^2}\frac{\mathrm{d}M}{\mathrm{d}t}, \tag{11}$$

It is seen that, if a black hole looses its mass (*i.e.* $\mathrm{d}M/\mathrm{d}t < 0$), the total energy of its Unruh radiation increases or we say that the black hole emits Unruh radiation. The emission rate of the radiation energy or the power of the Unruh radiation from a black hole is much lower than the rate of mass-energy loss from the black hole if the black hole is not micro-sized one. For example, when a 3 solar mass black hole looses its mass of one kilogram in one second, the emission power of Unruh radiation is only about 4×10^{-61} W, while the rate of mass-energy loss is 9×10^{16} W. Principally, as nothing can escape from it, a black hole does not emit Unruh radiation. A black hole does not evaporate unless we can find a physical process, through which matter can get out of the black hole.

At the surface of a black hole ($r = R$), the Unruh radiation temperature is given by [8]

$$T = \frac{\hbar}{2\pi c k_B}\frac{GM}{R^2} = \frac{\hbar c^3}{8\pi k_B GM}, \quad (12)$$

which is inversely proportional to the mass of the black hole. It is usually called the Hawking temperature of a black hole, $T \rightarrow T_H$ [10] [11]. Due to the emission of Unruh radiation, the change of entropy of a black hole can be given by,

$$\mathrm{d}S = \frac{\mathrm{d}Q}{T} = -\frac{\mathrm{d}U_\gamma}{T_H}. \quad (13)$$

Here Q is the heat of the black hole. The Unruh radiation of the black hole causes its energy or heat change, $\mathrm{d}Q = -\mathrm{d}U_\gamma$.

Integrating Equation (13) with the use of Equations (11) and (12) to replace $\mathrm{d}U_\gamma$ and T_H with respect to the mass of a black hole from an initial mass M_0 to the final mass M, we can find the entropy of the black hole with the final mass M as,

$$S - S_0 = -\int_{M_0}^{M}\frac{\mathrm{d}U_\gamma}{T_H} = \int_{M_0}^{M}\frac{k_B}{1200M}\mathrm{d}M = \frac{k_B}{1200}\ln\left(\frac{M}{M_0}\right), \quad (14)$$

where S_0 is the initial entropy of the black hole with the initial mass M_0. It is seen that the entropy of a black hole increases as it slowly grows by proportional to the natural logarithm of its mass. The entropy of a black hole does not decrease, as it never looses its mass. In general, the entropy of a black hole with mass M can be defined as an arbitrary constant Δ plus a small part of the mass-dependent entropy.

$$S = \Delta + \frac{k_B}{1200}\ln M, \quad (15)$$

Figure 2 shows the various parameters of Unruh radiation of a black hole as functions of the black hole's mass. The red line plots the Unruh radiation temperature of the black hole at its surface, given by Equation (12). The green line plots the ratio of the power of Unruh radiation and the rate of mass-energy loss, defined by $R_{\gamma M} = P_\gamma/(-c^2\mathrm{d}M/\mathrm{d}t)$ according to Equation (11). The purple line plots the total Unruh radiation energy of the black hole, given by Equation (9). And the blue line plots the entropy of the black hole, given by Equation (15) with the constant $\Delta = 0$. It is seen that both the Unruh radiation temperature at the surface of the black hole and the total Unruh radiation energy outside the black hole are inversely proportional to its mass. The rate of emission (or power)

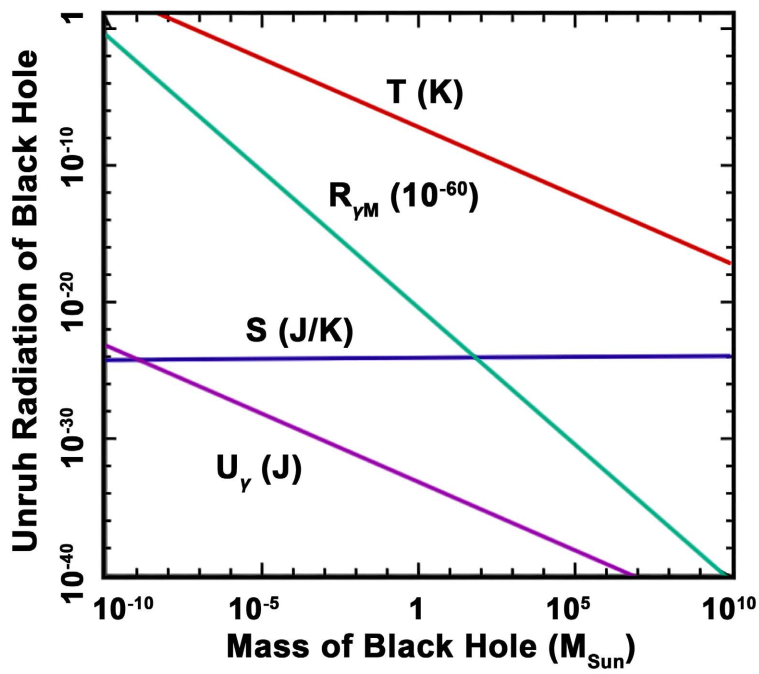

Figure 2. It plots various parameters for the Unruh radiation of a black hole as functions of its mass. These parameters include: 1) the Unruh radiation temperature at the surface of the black hole (red line), 2) the ratio of the power of Unruh radiation and the rate of mass-energy loss (green line), 3) the total Unruh radiation energy that surrounds the black hole (purple line), and 4) the entropy of the black hole (blue line).

of Unruh radiation is only a tiny part of the rate of mass-energy loss with a percentage to be inversely proportional to the square of its mass. The entropy of the black hole is extremely low if the constant Δ is not too much greater than the mass-dependent part of the entropy and slowly increases with its mass via the function of natural logarithm.

The above analysis for the quantum Unruh effect on radiation of black hole is quite different from the work done by Hawking in 1974 [10] [11]. This study does not apply the Stephan-Boltzmann (S-B) law with the Unruh radiation temperature at the surface of a black hole to determine the Unruh radiation power of the black hole. The reason is because the S-B law describes the intensity of the thermal radiation emitted by matter in terms of that matter's temperature and hence is not applicable to the Unruh radiation. The Unruh radiation results from the gravitational field of the body rather than the thermal heat of the body's matter. For the thermal radiation of a blackbody, the S-B law states that the radiant or total radiation energy emitted from a unit area of the blackbody in one second is directly proportional to the fourth power of the temperature of the blackbody. Applying the S-B law to the Unruh radiation of a static gravitational object will lead to some physical contradictions.

For instance, with the Unruh radiation temperature at the surface of the neutron star exampled above with mass of 1.5 solar masses and radius of 20 km, even though it is gravitationally static without accreting matter or shrinking size, the Stephan-Boltzmann law gives the power of Unruh radiation to be

$$P_{S\text{-}B} = 4\pi R^2 \sigma T^4 = \frac{\hbar G^4 M^4}{240\pi c^6 R^6} \sim 4.8\times10^{-33}\ \text{J/s}\,. \quad (16)$$

where σ is the Stephan-Boltzmann constant. This increases the neutron star's total Unruh radiation energy outside by about ten thousand times in just one second, which equivalently enhances the Unruh radiation temperature and hence the neutron star's gravitational field by ten times greater. This cannot be true and therefore unphysical because a gravitationally static object remains its gravitational field unchanged rather than generates a significant radially outward propagating gravitational field disturbance or wave. In addition, the temperature and energy density of the radiation derived by the S-B law depend on the radial distance in the ways very different from those of the Unruh radiation given in Equations (4) and (5). Therefore, we should not suggest that a gravitationally static object keeps continuously emitting the Unruh radiation at the flux determined according to the S-B law with the Unruh radiation temperature at the surface of the object.

4. The Hawking Radiation

But unbelievable, Hawking did it for a black hole in such unphysical way. He substituted the Unruh radiation temperature of a black hole at its surface into the S-B law to find the radiation power of the black hole. He further let the radiation power equal to the rates of mass-energy loss and heat change to find the evaporation time and entropy of the black hole. All these work done by Hawking were conceptually incorrect in physics, but unfortunately, no one has yet pointed it out and corrected that great mess or blunder on the black hole radiation. The following three paragraphs give a brief description of Hawking's work done in [10] [11] on the radiation of black hole.

Applying the S-B law with the Unruh radiation temperature given by Equation (12) and integrating the flux of the Unruh radiation over the surface of the black hole, Hawking obtained the power of radiation (widely called the Hawking radiation) from a black hole to be,

$$P_H = 4\pi R^2 \sigma T_H^4 = 4\pi R^2 \frac{2\pi^5 k_B^4}{15h^3c^2}\left(\frac{\hbar c^3}{8\pi k_B GM}\right)^4 = \frac{\hbar c^6}{15360\pi G^2 M^2}\,, \quad (17)$$

which is inversely proportional to the square of mass. Here we have applied the expression of the Stephan-Boltzmann constant. For a star-like black hole with 3 solar masses, we have the temperature and power of Hawking radiation to be $T_H \sim 2.04\times10^{-8}\ \text{K}$ and $P_H \sim 9.9\times10^{-30}\ \text{W}$, respectively. In just one second, this will raise the total Unruh radiation energy that surrounds the black hole by ten thousands times. This ten-thousand times increase of the total Unruh radiation energy equivalently makes the gravitational field of the black hole ten times stronger per second, which must be unphysical. A black hole no matter static or not radiate Hawking radiation.

Based on the Hawking radiation power Equation (17) to be equal to the rate of mass-energy loss, $P_H = -c^2 dM/dt$, Hawking further obtained the time needed (or the evaporation time) for a black hole to be completely radiated or evaporated out as

$$\tau_H = -\int_M^0 \frac{c^2}{P_H} dM = \frac{5120\pi G^2 M^3}{\hbar c^4}, \tag{18}$$

which is proportional to the cube of the mass. For the star-like black with 3 solar masses, it takes $\tau_H = 1.8 \times 10^{76}$ s to evaporate the black hole out. For a micro-sized black hole with the Planck mass (~2.18×10^{-8} kg), the Unruh radiation temperature at the surface, Hawking radiation power, and Hawking evaporation time are ~5.62×10^{30} K, 7.5×10^{47} W, and 8.7×10^{-40} s, respectively. The study as shown by Equation (11) finds that the Unruh radiation is only a tiny part (~10^{-80} for a star-like black hole) of mass-energy loss.

Considering the heat transfer to be equal to the mass-energy loss from the Hawking radiation, Hawking derived the entropy of a black hole to be given by

$$S_H = \int_0^M \frac{dQ}{T_H} = \int_0^M \frac{8\pi k_B GM}{\hbar c^3} c^2 dM = \frac{4\pi k_B GM^2}{\hbar c} = \frac{k_B c^3 \pi R^2}{4\hbar G}, \tag{19}$$

which is proportional to the square of its mass or radius (or the surface area of the black hole). The big coefficient implies that black holes have unbelievably large entropies. For instance, a star-like black hole with 3 solar masses has entropy of about $9.6 \times 10^{75} k_B \sim 10^{53}$ J/K, many orders in magnitude higher than that of its parent star. Due to the Hawking evaporation, a black hole can decrease its entropy and thus loose the information that enters the black hole. The

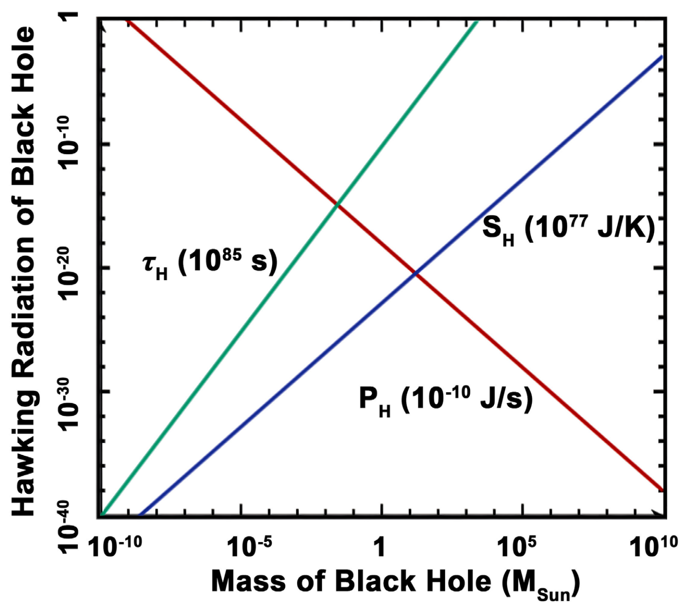

Figure 3. It plots various parameters for the Hawking radiation of a black hole as functions of its mass. These parameters include: 1) the Hawking radiation power of the black hole (red line), 2) the Hawking entropy of the black hole (blue line), and 3) the Hawking evaporation time of the black hole (green line).

study as shown by Equation (14) finds that the entropy of a black hole is very low (~$0.06k_B$ for a 3-solar mass black hole) and slowly increases with its mass.

Figure 3 shows the various parameters of the Hawking radiation of a black hole as functions of the black hole's mass. The red line plots the Hawking radiation power of the black hole, given by Equation (17). The blue line plots the Hawking entropy of the black hole according to Equation (19). And the green line plots the Hawking evaporation time of the black hole, given by Equation (18). It is seen that both the Hawking entropy and Hawking evaporation time increase with the black hole mass, while the power of Hawking radiation decreases with mass increase. For a star-like black hole, the entropy is many orders in magnitude greater than that of a star; the time of evaporation is also many orders in magnitude longer than the lifetime of the universe; while the power is many orders in magnitude lower than that of a single excited atom to emit a photon of light per second.

5. Discussions and Conclusions

These work done and results obtained by Hawking as briefly described above in Section 3 look great, but unphysical. The reason for this discrepancy is due to the Unruh radiation temperature at the surface of the object is not the object surface's actual matter's temperature, and hence the S-B law is not applicable. The Unruh radiation temperature is gravitational (resulting from the gravitational field of the object), inversely proportional to the square of radial distance that leads to the Unruh radiation flux or energy density to be inversely proportional to the eighth power of radial distance. Plugging the Unruh radiation temperature into the S-B law, as done by Hawking, does not give the power of Unruh radiation of a black hole. A gravitationally static black hole does not emit Unruh radiation as nothing can escape from the black hole.

This paper shows that the emission power of Unruh radiation from a gravitational object including a black hole should be calculated in terms of the rate of increase of the total Unruh radiation energy outside the object. The result obtained from this study indicates that a gravitational object can emit Unruh radiation when the variation of its mass and radius satisfies the condition $\mathrm{d}M/M > 1.25\mathrm{d}R/R$. For a black hole, the emission of Unruh radiation does not occur unless it can loose its mass. The emission power of Unruh radiation is only a tiny part of the rate of mass-energy loss if the black hole is not micro-sized. For a 3 solar mass black hole to loose 1 kg per second, the emission power of Unruh radiation is only about 4×10^{-61} W, while the rate of mass energy loss is 9×10^{16} W. The entropy of a black hole that is calculated based on the Unruh radiation temperature and the change of the total Unruh radiation energy is very low and slowly increases with its mass. This study turns down our traditional understanding of the Hawking radiation and thermodynamics of black holes and provides new insight and a conceptual correction regarding the quantum Unruh effect on the radiation of black holes.

Acknowledgements

The author acknowledges the support from the IBM-HBCU Quantum Center via the funded project.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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