The Spacetime and Finite-Size Nuclear Structure of the Black Hole

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Abstract The Schwarzschild metric describes a non-rotating and charge-free celestial body, and it results in things stopping at the event horizon of a black hole and spending infinite time across the event horizon by the observer far away from the black hole. The analysis of the particle's behavior at the event horizon tells us that this solution predicts an un-expanded black hole which violates the astronomical observations and our knowledge about the black hole. Although some alternative metrics have been proposed, the singularity problem is still unsolved. In this research, the degenerate Fermi electron gas is used to reveal that the Fermi electron gas cannot shrink to a point no matter how large energy it obtains, so the singularity exists at the center very unreasonably. In order to avoid these problems, a finite-size nucleus of the black hole is proposed and reasonably explained by the behaviors of the Fermi electron gas and the Fermi neutron gas there. On the other hand, the Kerr-Newman metric is the one describing the rotating and charged black hole and the equation of the light velocity at each space point can be obtained. It tells us that there are two real and non-imaginary solutions for the radial speed of light at the position larger than the Schwarzschild radius.

Keywords: Black hole, Schwarzschild radius, Kerr-Newman metric, geodesic, finite-size nucleus

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1. Introduction

Some candidates of the black holes have been found many years [1-3]. Although we don't know what the structure inside the black hole is, we can make sure that there is some heavy mass gathering in a small space which we call the outer boundary, the event horizon, of the black hole. Traditional theory considers the center of a black hole to be a singularity and all mass as well as all charges collect there [4]. The massive particles even light cannot escape the black hole when they are in it. But is it also true for light or a photon such a massless particle?

Recently, several times of gravitational waves from the mergers of binary black hole have been observed by LIGO and VIRGO [5-8]. Because the mass of each black hole exists within each own event horizon, the merger means that two event horizons have to intersect with each other, then their mass can merger, and finally several equivalent solar-mass energy was released. In fact, the mass of the new black hole is less than the summation of two original black holes. A problem is where does the lost mass go? It is just the merger causing collision between the two black holes and then resulting in mass lost. The lost mass transferred to other forms such as the gravitational wave and electromagnetic wave. These mergers revealed that the gravitational waves were from the collisions of inner structures of two black holes and they can pass through the event horizon to the outer space. Because the gravitational waves were from the collision of two black holes, then the spacetime structure outside the new black hole is changed due to the variation of the total mass. When the gravitational wave is confined in the black hole, the black hole is like a closed system and the spacetime structure outside it cannot change without the gravitational wave delivering some information about the variation of mass. In addition, the other observation from binary neutron star showed both receiving signals of gravitational waves and electromagnetic waves almost at the same time [9]. Since the gravitational wave and electromagnetic wave exist in the same spacetime structure of the same black hole and both of them follow the null geodesic, we might ask why the gravitational wave can leave the black hole but light cannot?

On the one hand, the singularity has unphysical infinite density in mass, charge, and energy there; on the other hand, the mergers of two black holes also imply the inner structure of the black hole to be a very high-density nucleus. It gives rise to a curiosity about whether this singularity is reasonable in a black hole or not. In this research, we first discuss this topic from the speed of light. Then we consider energy conservation applied on a black hole and its previous star to propose a finite-size nucleus in the black hole. Finally, the limitation of the nuclear size is discussed.

2. The Schwarzschild Metric And The Velocity Of Light In The Black Hole

Before obtaining deeper perspectives about the black hole, first, we discuss the propagation of light from the outer space passing through the event horizon into the non-rotating and uncharged black hole with a Schwarzschild radius R_S=2GM/c^2, where M is the mass of the black hole, c is the speed of light in free space, and G is the gravitational constant. This discussion is easy to check whether such kind of the black hole is reasonable or not. Its spacetime structure is described by the Schwarzschild metric and there is only one event horizon for this kind of black hole. The Schwarzschild metric [10-14] in the spherical polar coordinate (r, θ, ϕ) and the coordinate time t is expressed as

$$\mathrm{d}s^2 = \left(1-\frac{R_S}{r}\right)\mathrm{d}t^2 - \left(1-\frac{R_S}{r}\right)^{-1}\mathrm{d}r^2 - \mathrm{d}\theta^2 - r^2\sin^2\theta\mathrm{d}\phi^2, \tag{1}$$

where the coordinate time t in a gravitational field is the time read by the clock stationed at infinity because the proper time and coordinate time becomes identical [14]. Light propagates along the null geodesic with ds^2=0, and the velocity of light in the Schwarzschild metric has been obtained [10-13] which is

$$\frac{1}{\left(1-\frac{R_S}{r}\right)^2}\left(\frac{\mathrm{d}r}{dt}\right)^2 + \frac{1}{1-\frac{R_S}{r}}\left(r\frac{\mathrm{d}\theta}{\mathrm{d}t}\right)^2 + \frac{1}{1-\frac{R_S}{r}}\left(r\sin\theta\frac{\mathrm{d}\phi}{dt}\right)^2 = c^2. \tag{2}$$

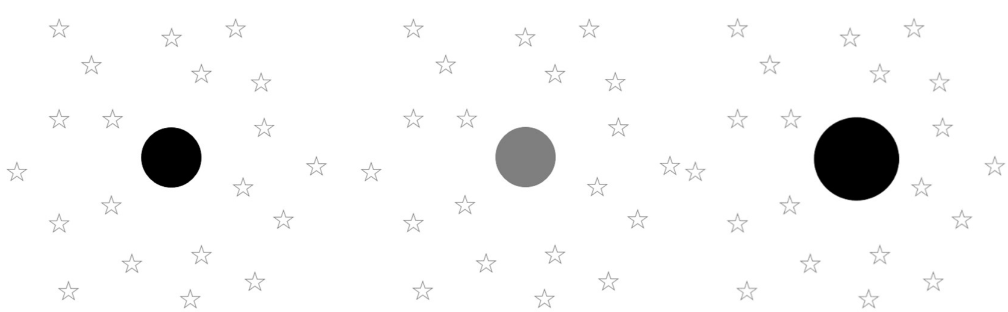
Considering light propagating along the radial direction with the radial velocity v_r, that is,

$$v_r^2 = \left(\frac{\mathrm{d}r}{dt}\right)^2 = \left(1-\frac{R_S}{r}\right)^2 c^2. \tag{3}$$

It gives v_r=0 at r=R_S where light has to spend infinite time passing through the event horizon. Furthermore, the velocity of light is imaginary at r<R_s. It is also true for the massive particle. Then considering a test massive particle, the spending time from r_0 to R_S is [9]

$$\int_{r_0}^{R_S} dt = \frac{A}{c}\int_{r_0}^{R_S} \frac{1}{\left(1-\frac{R_S}{r}\right)\sqrt{A^2-\left(1-\frac{R_S}{r}\right)}}dr, \tag{4}$$

where A is a constant. The integral in Eq. (4) gives the infinitely spending time from a finite distance r_0 to R_S. As we know, particles can really enter into the black hole, and the black hole can really expand and increase its mass [15]. However, Eqs. (3) and (4) cannot explain the expansion of the black hole due to nothing passing through the event horizon and then entering into the black hole by observations far away from the black hole. Without the accretion disk, this black hole should show a completely black region in space by observation which is schematically drawn in Fig. 1(a). When a lot of particles or bodies gradually accumulate at the event horizon without entering the black hole, an observer far away from the black hole will see it in Fig. 1(a) covering by some things as shown in Fig. 1(b). All those things are non-rotating and stop there, and they are squeezed to become a very thin layer with ultra-high density. As a result, Eqs. (2) and (3) deduced from the Schwarzschild solution predict a planet-like body, not an unobservable black hole. It means that if all things stop at the event horizon surrounding the black hole by observations far away from it, an observer will not find a region so called the black hole as shown in Fig. 1(a) in space. Besides, Eqs. (3) and (4) also give a result that the black hole cannot grow up. As mentioned before, the black hole can really expand by increasing its mass as schematically shown in Fig. 1(c). When we observe all things stopping at the event horizon, we cannot investigate this expansion. It is about the causality. Without the truth that massive things passing through the event horizon and devoured by the black hole, it is very hard to explain how its mass increases observed on earth.



(a) (b) (c)

Fig. 1 (a) A schematic picture of a black hole in space. It is a black region by astronomical observation. (b) The predicted black hole from the Schwarzschild metric. Due to all things stopping at the event horizon and surrounding the black hole observed far away from the black hole, the astronomical observations show a region covering things like a planet, not a completely black region. (c) The black hole can expand due to some massive particles passing through the event horizon and really devoured by the black hole. However, Eq. (4) cannot predict this phenomenon.

Even in the past, some metrics tried to delete this singularity at r=R_S, such as the timelike Edditong-Finkelstein coordinates [11,13,14] and the Kruskal-Szekeres coordinates [10,11,13,14], they still cannot solve the problem perfectly. The variable v in the timelike Eddington-Finkelstein coordinates is defined as

$$v = t + \frac{r}{c} + \frac{R_S}{c} \ln\left|\frac{r}{R_S} - 1\right|. \tag{5}$$

Although it avoids the singularity at r=R_S in the new transferring metric, itself is divergent at r=R_S. It doesn't real avoid the singularity. Another one metric for replacement, the Kruskal-Szekeres coordinates, adopt the transformation [11]

$$\begin{cases} v = (1 - r/R_S)^{1/2} e^{r/2R_S} \cosh t/2R_S \\ u = (1 - r/R_S)^{1/2} e^{r/2R_S} \sinh t/2R_S \end{cases} \quad for\ r < R_S \tag{6a}$$

and

$$\begin{cases} v = (r/R_S - 1)^{1/2} e^{r/2R_S} \sinh t/2R_S \\ u = (r/R_S - 1)^{1/2} e^{r/2R_S} \cosh t/2R_S \end{cases} \quad for\ r > R_S. \tag{6b}$$

This transformation cannot connect from r<R_S to r>R_S at r=R_S and it is still unsolved perfectly. The problem of the singularity at r=R_S still exists in both coordinates because the singularity problem has already existed in the original Schwarzschild metric. Another way to delete the singularity at r=R_S is using the falling-in observer to discuss the falling freely particle along the radial direction from initial place r_0 at rest to R_S. In this way, the spending time is

$$\Delta\tau = \frac{2R_S}{3c}\left[\left(\frac{r_0}{R_S}\right)^{3/2} - 1\right]. \tag{7}$$

However, this finite proper time interval doesn't solve the problem of singularity at r=R_S because we cannot proceed the real experiment very close to the black hole now, and all the astronomical observations are on earth far away from the black hole. As we know, the time on earth is almost the same as the coordinate time at infinity. When we want to compare the Schwarzschild solution with the observations, we have to adopt the coordinate time on earth or at infinity, not the viewpoint of the observer at the local coordinate in the vicinity of a black hole. Its result is similar to Fig. 1(b) which is the conclusion given by Eq. (4).

In conclusions, when we adopt the Schwarzschild solution to describe the spacetime structure in the vicinity of a black hole, it results in a planet-like body and cannot explain the expansion of the black hole. Furthermore, the speed of light at r≤R_S is also unreasonable. According to these, we have to give up some concepts of the Schwarzschild metric that all things stop at the event horizon and the speed of light is zero there. We need to use another metric to explain the black hole reasonably. In addition, all stars or planets we have observed are rotating so the Schwarzschild metric is impractical or just good approximation in some situations.

3. The Kerr-Newman Metric and the velocity of light in the black hole

There are other metrics to discuss the Einstein's spacetime structure, such as the Kerr-Newman metric [16] describing the rotating and charged black hole. The accretion disc is made up of a lot of plasma and electrons, so the material that the black hole swallows contains positively and negatively electric substances, and it is difficult to maintain a black hole that is electrically neutral at any time. Therefore, it is a more reasonable choice to consider rotating and charged black holes. This metric is expressed in the spherical polar coordinate (r, θ, ϕ) and the coordinate time t as

$$\mathrm{d}s^2 = -\left(\frac{\mathrm{d}r^2}{\Delta} + \mathrm{d}\theta^2\right)\rho^2 + (c\mathrm{d}t - a\sin^2\theta\mathrm{d}\phi)^2\frac{\Delta}{\rho^2} - \left((r^2 + a^2)\mathrm{d}\phi - ac\mathrm{d}t\right)^2\frac{\sin^2\theta}{\rho^2}, \tag{8}$$

where $\rho^2 = r^2 + a^2\cos^2\theta, \Delta = r^2 - rR_S + a^2 + R_Q^2$, $a=J/Mc$ with the angular momentum of a black hole J, and $R_Q^2 = KQ^2G/c^4$ with the Coulomb's constant K and total charge Q of a black hole. The coordinate time t in Kerr-Newman metric is also the time read by the clock stationed at infinity because the proper time and coordinate time becomes identical [14]. Similar to Eq. (2), Eq. (8) gives the relationship between three velocity components of light ($\mathrm{d}r/\mathrm{d}t$, $r\mathrm{d}\theta/\mathrm{d}t$, $r\sin\theta\mathrm{d}\phi/\mathrm{d}t$) in the Kerr-Newman metric which is

$$\frac{\rho^4}{\Delta(\Delta - a^2\sin^2\theta)}\left(\frac{\mathrm{d}r}{dt}\right)^2 + \frac{\rho^4}{r^2(\Delta - a^2\sin^2\theta)}\left(r\frac{\mathrm{d}\theta}{\mathrm{d}t}\right)^2 - \frac{(\Delta a^2\sin^2\theta - (r^2 + a^2)^2)}{r^2(\Delta - a^2\sin\theta)}\left(r\sin\theta\frac{\mathrm{d}\phi}{dt}\right)^2 - \frac{2ac(-\Delta + (r^2 + a^2))\sin\theta}{r(\Delta - a^2\sin^2\theta)}\left(r\sin\theta\frac{\mathrm{d}\phi}{dt}\right) = c^2. \tag{9}$$

The reasonable way to use Eq. (9) is each velocity component real and finite. We have discussed the radial speed of light for the rotating and charged black hole [17]. Especially, if we want to discuss light propagating into a black hole, the radial speed of light at the event horizon must be nonzero. The Kerr-Newman metric has a mathematical singularity at r=0 and $\theta = \pi/2$. It is the problem due to a singularity with infinite mass density at the center of the black hole. If we adopt a finite-size nucleus for a black hole, this mathematical singularity can disappear automatically. This can be reasonably explained later. Except for this metric, there are some others [18-20] or alternative coordinates describing the spacetime structures for the black hole. However, those metrics giving an infinite time for any happening at the event horizon and non-rotating case are unphysical as discussed before.

By Eq. (9), the radial velocity v_r of light propagating along the radial direction at the black hole is

$$v_r = \frac{dr}{dt} = \pm \frac{\rho^2}{\sqrt{\Delta(\Delta - a^2 sin^2\theta)}} c. \tag{10}$$

It clearly shows that the radial velocity is real, nonzero, and non-imaginary everywhere at $r>R_S$ no matter how large a and R_Q are. Eq. (10) gives two solutions at the outer event horizon [16], one is in and the other is out the event horizon. The Kerr-Newman metric avoids the problems in Eq. (3) and is useful for describing most black holes reasonably so the spacetime described by the Kerr-Newman metric is a reasonable one.

4. The Reasonable Behavior Of Light At The Event Horizon

Next, let us discuss the reasonable behavior of light propagating along the radial direction. As mentioned before, the supermassive black holes [1,3] mean that the particles really enter the black hole during finite time, and the zero or imaginary velocity for light or massive particles is unreasonable.

According to the nowadays theory of the black hole, once light propagates into the black hole, no light can escape the black hole. In order to re-check this viewpoint, three possibilities are discussed for light emitted from the center of the black hole. The first possibility is that light can propagate away from the black hole, the second one is that light eventually stops at the event horizon, and the third one is that light comes back to the singularity. If the gravity of the black hole doesn't change during the light propagation, Eq. (10) tells us that the radial speed of light has two solutions with the same value but different signs at the outer event horizon [16]: one is into the black hole and the other is away from the black hole. Furthermore, the radial speed of light at the event horizon is non-zero. Light should not stop at the event horizon and continuously propagate across the event horizon. It also reveals that if light can propagate into the black hole, it also can propagate from the inner of a black hole to the outer space along the same geodesic.

The second possibility seems to give a contradiction. Basically, the geodesic of light is continuous at the event horizon. When light from the inner of the black hole stops at the event horizon, it means that light from the outer space on the same geodesic also stops there. However, as mentioned previously, light cannot stop at the event horizon. Otherwise, it predicts an unobserved black hole which violates the astronomical observations. It is not a reasonable description for light stopping at the event horizon no matter how small energy it is.

The third possibility is that light doesn't stop at r=R_S and return back to the singularity. Even light return back at the event horizon, it would have a possibility that light come back to the singularity without any absorption, then light will pass it and propagate toward to the other side of the black hole. It is possibly back and forth repeating the same trajectory. The third situation meets a problem similar to the second situation that it has to stop at the event horizon and the geodesic of light is closed within the event horizon and no geodesic connects with the outer space at the event horizon. It is also an unreasonable description for the propagation of light in the black hole.

In summary, only the first situation is reasonable for light propagating in the black hole. Furthermore, the appropriate metric for describing the spacetime at a black hole is not the one which results in anything spending infinite time across the event horizon. The Kerr-Newman metric is a good choice not only it can avoid the above problem, but also most black holes possess rotation and easily charged in nature.

5. The Finite-Size Nucleus In The Black Hole

Since a lot of black holes are evolutional from stars with totally finite energy, the initial black hole should also have finite energy. Theoretically speaking, the black hole should have a finite-size nucleus in it. Here we adopt the part of the white dwarf model at absolute zero temperature where N Fermi electrons and $N/2$ helium nuclei coexist at the final stage of a super star to prove it [21,22]. The volume of the star with radius of R_0 is

$$V_0 = \frac{4}{3}\pi R_0^3, \tag{11}$$

and the total mass of the star is

$$M \approx (m_e + 2m_n)N \approx 2m_n N, \tag{12}$$

where m_e is the electron mass and m_n the neutron mass. Then at temperature T=0 K, the total kinetic energy of the Fermi electron gas in the ultrarelativistic condition is [22]

$$U_e \approx \frac{2\pi V_0 m_e^4 c^5}{h^3}\left(\frac{p_f}{m_e c}\right)^4 = \frac{2\pi V_0 p_f^4 c}{h^3} = \frac{3Nhc}{4}\left(\frac{3N}{8\pi V_0}\right)^{1/3}. \tag{13}$$

where the momentum of the Fermi electron is

$$p_f = h\left(\frac{3N}{8\pi V_0}\right)^{1/3}. \tag{14}$$

The total kinetic energy of helium nuclei is almost zero because they are Boson gas. The total energy of the star without Coulomb's energy at the final stage is

$$U_{total} \approx U_e + Nm_e c^2 + 2Nm_n c^2 + U_g$$

$$\approx \frac{3Nhc}{4}\left(\frac{3N}{8\pi V_0}\right)^{1/3} + Nm_e c^2 + 2Nm_n c^2 + U_g, \quad (15)$$

where the self-energy of gravity is

$$U_g = \frac{3GM^2}{5R} \approx \frac{3G(2m_n N)^2}{5}\left(\frac{4\pi}{3V_0}\right)^{1/3}. \quad (16)$$

Here the self-energy is calculated by considering a homogeneous star.

Next, we consider one negative charged case that some Fermi electron gas existing at the center of the black hole to check whether it has a singularity at the center or not. It means negative charges are more than positive ones, and one situation is that the center consists of some neutral part and the Fermi electron gas. Eq. (13) tells us that U_e has infinite energy when V_0 is close to zero. However, it is impossible for electron gas to become a singularity point because it needs infinite energy revealed by Eq. (13). When the gravitational collapse [10,11,13] is discussed, the Fermi electron gas is a good example to check whether the gravitational collapse is reasonable or not [23].

Then we consider another formation of a black hole. Due to the supernova producing ultra-high pressure, the most of electrons and protons react to become neutrons. After that, it theoretically exists $2N$ neutrons there. Because of the supernova, in fact, αN neutrons transfer to the radiation energy and $(2-\alpha)N$ neutrons are still there. Then the total kinetic energy of the rest $(2-\alpha)N$ neutrons within the volume V in the ultrarelativistic condition is [22]

$$U_N \approx \frac{2\pi V m_n^4 c^5}{h^3}\left(\frac{p_f}{m_n c}\right)^4 = \frac{2\pi V c p_f^4}{h^3} = \frac{3(2-\alpha)Nhc}{4}\left[\frac{3(2-\alpha)N}{8\pi V}\right]^{1/3}, \quad (17)$$

where the momentum of Fermi energy for the neutron gas is

$$p_f = h\left[\frac{3(2-\alpha)N}{8\pi V}\right]^{1/3}. \quad (18)$$

The total energy of these $(2-\alpha)N$ neutrons is

$$U_{total}^{rest} \approx U_N + (2-\alpha)Nm_n c^2 + U_g^{rest}$$

$$\approx \frac{3(2-\alpha)Nhc}{4}\left[\frac{3(2-\alpha)N}{8\pi V}\right]^{1/3} + (2-\alpha)Nm_n c^2 + U_g^{rest}, \quad (19)$$

where the self-energy of gravity forming those $(2-\alpha)N$ neutrons is

$$U_g^{rest} = \frac{3G(2-\alpha)^2 m_n^2 N^2}{5}\left(\frac{4\pi}{3V}\right)^{1/3}. \quad (20)$$

Considering energy conservation, it gives

$$U_{total}^{rest} < \frac{3(2N)hc}{4}\left[\frac{3(2N)}{8\pi V_0}\right]^{1/3} + 2Nm_nc^2 + U_g < \infty. \quad (21)$$

From Eq. (21), it clearly shows that $V>0$ and $V<V_0$ so the (2-α)N neutrons form a finite-size volume, and they cannot become to a point.

6. The Range of The Nuclear Size In The Black Hole

Furthermore, Eq. (21) also gives

$$\alpha Nm_nc^2 + \left[2(2)^{1/3} - (2-\alpha)(2-\alpha)^{1/3}\left(\frac{1}{\beta}\right)^{1/3}\right]\frac{3Nhc}{4}\left(\frac{3N}{8\pi V_0}\right)^{1/3} + \frac{3Gm_n^2N^2}{5}\left[4-(2\alpha-\alpha)^2\left(\frac{1}{\beta}\right)^{1/3}\right]\left(\frac{4\pi}{3V_0}\right)^{1/3} > 0, \quad (22)$$

where $V=\beta V_0$ with $0<\beta<1$. When α is small and considering the Taylor expansion to the linear term for $(2-\alpha)^{1/3}$, then Eq. (22) becomes

$$\alpha Nm_nc^2 + 2(2)^{1/3}\left[1-\left(1-\frac{\alpha}{2}\right)\left(1-\frac{\alpha}{6}\right)\left(\frac{1}{\beta}\right)^{1/3}\right]\frac{3Nhc}{4}\left(\frac{3N}{8\pi V_0}\right)^{1/3} + \frac{3Gm_n^2N^2}{5}\left[4-(4-4\alpha+\alpha^2)\left(\frac{1}{\beta}\right)^{1/3}\right]\left(\frac{4\pi}{3V_0}\right)^{1/3} > 0. \quad (23)$$

After arranging

$$\alpha m_nc^2(\beta)^{1/3} + 2\left[(\beta)^{1/3} - 1 + \frac{2}{3}\alpha - \frac{1}{12}\alpha^2\right]\frac{3hc}{4}\left(\frac{3N}{4\pi V_0}\right)^{1/3} + \frac{3}{5}Gm_n^2N\left[4(\beta)^{1/3}-(4-4\alpha+\alpha^2)\right]\left(\frac{4\pi}{3V_0}\right)^{1/3} > 0. \quad (24)$$

Then solving α, the range is

$$2 - \frac{\left\{(square\ root\ term) - \left[m_nc^2(\beta V_0)^{1/3} + \frac{hc}{2}\left(\frac{3N}{4\pi}\right)^{1/3}\right]\right\}}{\left[\frac{hc}{4}\left(\frac{3N}{4\pi}\right)^{1/3} + \frac{6}{5}Gm_n^2N\left(\frac{4\pi}{3}\right)^{1/3}\right]} < \alpha < 2, \quad (25)$$

where the square root term is

$$\begin{aligned} square\ root\ term &= \Big\{ m_n^2 c^4 (\beta V_0)^{2/3} \\ &+ \left[2m_n c^2 + hc \left(\frac{3N}{4\pi}\right)^{1/3} + \frac{12}{5} G m_n^2 N \left(\frac{4\pi}{3}\right)^{1/3} \right] \left[hc \left(\frac{3N}{4\pi}\right)^{1/3} \right. \\ &\left. + \frac{12}{5} G m_n^2 N \left(\frac{4\pi}{3}\right)^{1/3} \right] (\beta)^{1/3} - \frac{1}{4} h^2 c^2 \left(\frac{3N}{4\pi}\right)^{2/3} (\beta)^{1/3} \\ &+ \frac{1}{4} h^2 c^2 \left(\frac{3N}{4\pi}\right)^{2/3} \Big\}^{1/2} . \end{aligned} \quad (26)$$

This α ranges approximately gives the exhaust of neutron particles in the event of supernova. Eq. (25) can estimate the mass of a black hole and its nuclear volume within the event horizons [16] considering the number of neutrons in the original star.

Recently, the similarity between the neutron star and the black hole has been discussed [23]. The compression of neutrons and helium atoms under extreme pressure has been studied [24,25]. Neutron and proton are both baryons composed of quarks and gluons. They have much ability to change their sizes and the force inside them is the strong interaction which is 10^{39} times larger than the gravity. The experiment about the distribution of pressure inside the proton also showed the average peak pressure about 10^{35} pascals near the center of a proton [26]. This pressure exceeds the pressure estimated the most neutron stars. When we compress the rest (2-α)N neutrons, they can become much smaller as shown in the quark-matter phase diagrams [27,28] and all the volume V is within the event horizon of a black hole. The evolution from the star to a black hole should follows energy conservation, and the black hole reasonably has a finite-size nucleus in it, not a singularity.

7. Conclusion

In summary, the reasonableness of the singularity of the black hole is studied in this paper. When we consider that everything in the black hole collecting at singularity, the infinite density of mass, charge, gravitational energy, and electric energy would be very unphysical. It gives rise to a curiosity why all mass as well as all charges gather at a point? Such structure doesn't obey energy conservation that the black hole is evolutional from a star with finite energy. The traditional theory of the Schwarzschild black hole also thinks everything even light stopping at the event horizon because they have to spend infinite time to pass through the event horizon. It results in a fact that the black hole is covered by a lot of things like a planet so theoretically speaking, we cannot observe a completely black region what we called the black hole. This makes the theory predict a planet-like body, not a black hole in space, and it is contradiction to the astronomical observations. It also cannot explain the expansion of the black hole due to absorptions of massive things [1,3]. Actually, we have to think physics more logically, not just believe something we have learned. If we believe the singularity in the black hole, we just believe the knowledge in 1920s or 1930s, one hundred years ago. In that age, people still had no deep ideas about neutron, they even didn't know what are the strong interaction and quarks. They just treated a mathematical solution as the real physical object without any believable proof about the physical truth of it. When we put the black hole and the big bang together, we will see it very clearly that the singularity is just a contradictive concept. The ultra-super strong gravity of the singularity before the big bang will affect the explosion and stop the expansion of the universe.

From the Kerr-Newman metric, we build the relationship of the three velocity components at each point for light in the black hole. If the singularity is replaced with the finite-size nucleus in the black hole, then the mathematical singularity in the Kerr-Newman metric at r=0 and $\theta = \pi/2$ is automatically disappeared. For the special case of a=0 and R_Q=0, it tells us that there are two solutions for the radial speed at the Schwarzschild radius. Especially, the investigations of gravitational waves from binary black holes reveal that gravitational waves can escape black holes away from their inside [5-8]. Theoretically speaking, light and the gravitational wave follow the same spacetime structure at the black hole and their trajectories are the null geodesic. It means that light should escape the black hole.

Finally, an example of the degenerate Fermi electron gas is used to check whether the singularity exists or not. It clearly shows that no matter how large the energy of the Fermi electron gas is, those electrons cannot shrink to a point. They always have finite volume discussed in statistical mechanics. The singularity also tells us that gravitational energy and Coulomb's energy are infinite there. Since a lot of black holes are evolutional from stars with finite energy, it is unreasonable to have infinite energy for black holes. Then we use the neutron gas as the most possible constituents after supernova to discuss their volume based on energy conservation. The result also tells us the similar result as we have already known in the Fermi electron gas so theoretically speaking, a black hole has a finite-size nucleus inside it, not a singularity.

Our conclusion is that the finite-size nucleus of the black hole is much reasonable. The Kerr-Newman metric for describing the rotating and charged black hole is an appropriate one for the spacetime description. In addition, the finite-size nucleus of the black hole can possess the magnetic dipole producing the magnetic force on the charged particle. The relativistic jet from the two poles outer the black hole is easily to explain due to the charged plasma motion along the strong magnetic field producing by the black hole.

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