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ROTATING CHARGE BLACK HOLES SHADOW SURROUNDED BY QUINTESSENCE

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Abstract

The Event Horizon Telescope Collaboration just took an image of M87 using the extremely long baseline interferometry technique. Aside from marking yet another milestone in the study of the strong field region's space-time geometry this shows that astrophysics will have a bright future. Dark energy (DE) is a big part of the reason our universe is expanding faster, according to a lot of data on the universe. Here, we looked at the shadows of rotating charge black holes surrounded by pure energy. We then compared our findings to those of Kerr-Newman black holes, and we found that our findings were very similar. This is what we found out during our research: The paradigmatic charge rotating black hole is a little smaller than the Kerr-Newman black hole for fixed values of the spin parameter. Black holes are extremely black astronomical gravitational objects, and we must test general relativity near them in order to gain a deeper knowledge of gravity.*

Keywords: rotating, charge, black holes, shadow, quintessence, etc

1. INTRODUCTION

The Event Horizon Telescope Collaboration just took an image of M87* using the extremely long baseline interferometer technique. Aside from marking yet another milestone in the study of the strong field region's space-time geometry also, this shows that astrophysics will have a bright future. The Van Cittert–Zernike theorem was used to figure out how the Fourier transform of the brightness distribution was calculated. This is how the Fourier transform was calculated. People who study black holes know that some of the image's optical features are entirely controlled by the black hole's own properties, like how much mass and charge it has and how quickly it spins around. People use them to get right down to the little thing. On the practical side, though, the image is still very much based on the structure of the black hole's accretion disc and how it moves at this point. As more and more research on planets goes on,it is envisaged that photos with significantly higher resolution will eventually be obtained, allowing the photon rings to be unequivocally detected. As a result, investigations of black hole shadow have sparked a fresh interest in recent years on the theoretical side. The faster expansion of the Universe means that matter with negative pressure, such as the cosmological constant or so-called quintessence matter, plays a big role in how the Universe came to be. If quintessence matter is everywhere in the Universe, it must be there might potentially exist in the vicinity of a black hole.

1.1 In classic dark energy, a rotating charged black hole casts a shadow

Examining the invisible parts of our Cosmos has piqued the interest of many scholars in recent years. Dark energy (DE) is a big part of the reason our universe is expanding faster, according to a lot of data on the universe. DE makes up about 70% of the universe we can see. This could be because of a repulsive cosmological constant > > 0 or a quintessential field. The parameter can be assumed to be homogenous because its value stays the same across space (1.3 1056cm2). It's not just the cosmological constant that is important about the DE. It also has a lot to do with quintessence. DE's contents, such as a quintessence field and a black hole's cosmological constant, have had a big effect on the shape of space and time (BH). It changes the structure of a BH when there is a cosmological constant in the world. When Bardeen found that a BH's shadow radius is about 5.2M over a background source, he came up with the idea of a shadow (visible to an external observer).

Most of the time, the shadows that spinning BHs make are about the same size. If you look at the shadow made by BH horizons in a theoretical way, you can see if there are photons and geodesics. BH looks like a dark disc to someone who isn't inside the BH. This is called the BH shadow. The shadow of non-rotating BHs looked like a circle. The shadow of rotating BHs looked like it was flattened on one side instead of a circle.Many academics have been inspired by recent astrophysics advances to look into the shadows created by BHs. Direct investigations of the BHs may soon be possible, according to researchers. Studying a BH's shadow will be a beneficial technique to better comprehend astrophysical BHs in the future, as well as to compare general relativity to present theories. The techniques In order to get more information about BHs, things like null geodesics and gravitational lensing are very important. Scientists have just taken the first picture of a super massive black hole (SMBH) at the centre of the M87 galaxy. Some people say this is the most conclusive proof of black holes, which opens up new ideas. avenues for BH research.

2. REVIEW OF THE LITERATURE

Chengxiang Sun, Yunqi Liu, Wei-Liang Qian, and Ruihong Yue (2022) the optical features a family of rotating black hole spacetimes are looked at in this paper. The black holes in question are thought to be in the quintessence field, and the black hole shadows should be changed by the presence of dark energy. The photon region and the shadow of a black hole are looked at, with a focus on how they affect important physical parameters like the quintessence state parameter, angular momentum, and the angular momentum. and magnetic charge magnitude. The photon areas are demonstrated to be sensitive to the horizon structure and to have complicated features. Furthermore, we investigate a few observables from the perspective of a static observer, particularly those related to the distortion of the seen black hole shadows.

Ren, Jingli, and Saeed Ullah Khan (2020) the presence of critical dark energy in the vicinity of a black hole has a big effect on how its spacetime geometry looks. As a result, we look at how it affects the horizons and the silhouette of a Kerr–Newman black hole in classic dark energy in this piece. We also use the Gauss–Bonnet theorem to figure out the angle at which light bends. The results show that the shadow of the black hole spins out in the direction of the rotating axis, while the deflection angle rises because of the drag. On the other hand, a black hole's charge cuts down on its shadow and the angle at which light is deflected. There is also the fact that both spin and charge make things distort more in the shadows of a black hole. Increases the shadow radius when the charge and spin parameters are higher. At the same time, the quintessence parameter makes it less blurry impact.

Carlos Benavides-Gallego, Ahmadjon Abdujabbarov, and Cosimo Bambi (2018) Using the Newman-Janis method, we created a black hole that spins and is magnetically charged is surrounded by quintessence. We looked at the event horizons, the ergosphere, and the ZAMO when we used the state parameter $omega q=-3/2$. We found out that the existence of the outer horizon is limited by the charge Q values, which we found out. We also found that when both the charge Q and the spin parameter a are raised, the ergo-region grows. Circular geodesics, photon geodesics, and the innermost stable circles were all looked at in the case of equatorial circular orbits. We looked at how the static radius affects how many geodesics, photon geodesics, and stable circles there are (ISCO). Q doesn't have a big effect on the way photons make circular orbits, and we show that $r ISCO$ is limited by the charge values that are used.

Balendra Singh (2017) Quintessence lets us look at the shadow of rotating charge black holes. When a black hole rotates, it makes its shadow look wavy. In our research, we found that the shape and size of the shadow are determined by four factors: charge, spin parameter, fundamental field parameter, and normalisation factor. One way that $omega q$ is linked to pressure is the equation of state $p=omega q-rho q 1/3$. This means that it can have a value between $-1omega q-1/3$ and $omega q-1/3$. In this study, we use the Hamilton-Jacobi equation and the Carter constant separable method to figure out the full geodesic structure of photons near black holes. $omega q=-2/3$: We connect celestial coordinates to the geodesics equation and draw the contour of the black hole's shadow on a map of the sky. The black hole's shadow gets smaller and more distorted with c if we keep the values of a and q the same. It's because of the black hole's optical properties that, because of the photon sphere's size, is equal to the area of the high-energy cross section. We figure out the cost. black hole's energy output rate based on this assumption.

3. OBJECTIVES

- To find out classic dark energy, a rotating charged black hole casts a shadow.
- To evaluate black hole surrounded by quintessence charge.

4. BLACK HOLE SURROUNDED BY QUINTESSENCE CHARGE

4.1 Non-rotating charge black hole surrounded by quintessence

In the presence of quintessence, the metric of a spherically symmetric static charge black hole with geometric units G = c = 1 reads

$$ds^2 = -f(r)dt^2 + \frac{1}{f(r)}dr^2 + r^2 d\Omega^2, \quad (1)$$

With

$$f(r) = 1 - \frac{2M}{r} + \frac{q^2}{r^2} - \frac{c}{r^{3\omega_q+1}} \quad (2)$$

Where M denotes the mass of the black hole, q the charge of the black hole, ωq the fundamental field parameter, and c the normalization factor the normalization factor is connected to the density of quintessence matter via

$$\rho_q = -\frac{c}{2}\frac{3\omega_q}{r^3(\omega_q+1)} \quad (3)$$

ρq > 0 is the density of quintessence matter. As a result, the normalisation factor has +ve values (c > 0) for -ve state parameter (ωq < 0) values. The quintessential state parameter explains the features of black hole metric and can have values in the range of $-1 < \omega q < -1/3$. The black hole metric is asymptotic flat for values of ωq in between $-1/3 < \omega q < 0$. The black hole metric has a de Sitter horizon for $-1 < \omega q < -1/3$, which gives the explanation for the accelerating universe's expansion. The black hole metric is reduced to Reissner-Nordstrom spacetime when $c = 0$.

4.2 Quintessence-encircled rotating charge black hole

When the Newman-Janis algorithm is used on the Reissner-Nordstrom black hole that is filled with quintessence, the Kerr-Newman black hole metric changes. surrounded by quintessence can be derived. The metric in the Boyer-Lindquist coordinate is of the type

$$ds^2 = -\left(1 - \frac{2Mr - q^2 + cr^{1-3\omega_q}}{\Sigma}\right) dt^2 + \frac{\Sigma}{\Delta} dr^2 - \frac{2a\sin^2\theta(2Mr - q^2 + cr^{1-3\omega_q})}{\Sigma} d\phi dt$$

$$+\Sigma d\theta^2 + \sin^2\theta\left(r^2 + a^2 + a^2\sin^2\theta\frac{2Mr - q^2 + cr^{1-3\omega_q}}{\Sigma}\right) d\phi^2, \quad (4)$$

Where

$$\Delta = r^2 - 2Mr + a^2 + q^2 - cr^{1-3\omega q} \; (5)$$

$$\Sigma = r^2 + a^2 \cos^2\theta. \; (6)$$

The black hole metric reduces to Kerr-Newman black hole in the case of $c = 0$, and to the generic Kerr black hole in the limit of $q = 0$.

5. NULL GEODESICS

If you don't have the spin parameter, the shadow of the black hole looks like a dark circle that isn't right. It looks like this: It's in this section that we look at the full geodesic structure of a test particle when it's surrounded by rotating charge black holes. When we want to look at the whole geodesic equation of motion, we use the Hamilton-Jacobi equation and the Carter method to do it. When the Hamilton-Jacobi equation first came out, everyone used the same method for solving it. During our research, we keep the important parameter $q = 2/3$ at the same value. The black hole metric is also the same. calculated for this value.

$$\begin{aligned} ds^2 &= -\left(1 - \frac{2\varrho r}{\Sigma}\right) dt^2 + \frac{\Sigma}{\Delta} dr^2 - \frac{4a\varrho r\sin^2\theta}{\Sigma} d\phi dt \\ &+\Sigma d\theta^2 + \sin^2\theta\left(r^2 + a^2 + a^2\sin^2\theta\frac{2\varrho r}{\Sigma}\right) d\phi^2, \end{aligned} \quad (7)$$

Where

$$\begin{aligned}\Delta &= r^2 - 2\varrho r + a^2,\\ \varrho &= M + \frac{c}{2}r^2 - \frac{q^2}{2r},\\ \Sigma &= r^2 + a^2\cos^2\theta.\end{aligned}$$

The Hamilton-Jacobi equation in its most general form is as follows:

$$\frac{\partial S}{\partial \sigma} = -\frac{1}{2}g^{\alpha\beta}p_\alpha p_\beta \qquad (8)$$

Where $p\alpha = \partial S/\partial x^{\alpha}$, σ is the Jacobean action, and A is the affine connection. We are now considering a separable solution for the Jacobi action S as follows:

$$S = \frac{1}{2}{m_0}^2\sigma - \mathcal{E}t + \mathcal{L}\phi + S_r(r) + S_\theta(\theta) \qquad (9)$$

Energy and angular momentum are represented by the constants ε and L, respectively. In the case of null geodesics or photons, m_0 is the mass of the test particle, which is zero. The coordinates t, φ in the black hole metric (7) are cyclic, and two conserved quantities ε and L correspond to these cyclic coordinates. We find the entire geodesics equations of motion for photons around the rotating charge black hole surrounded by quintessence using the variable separable approach, which take the form:

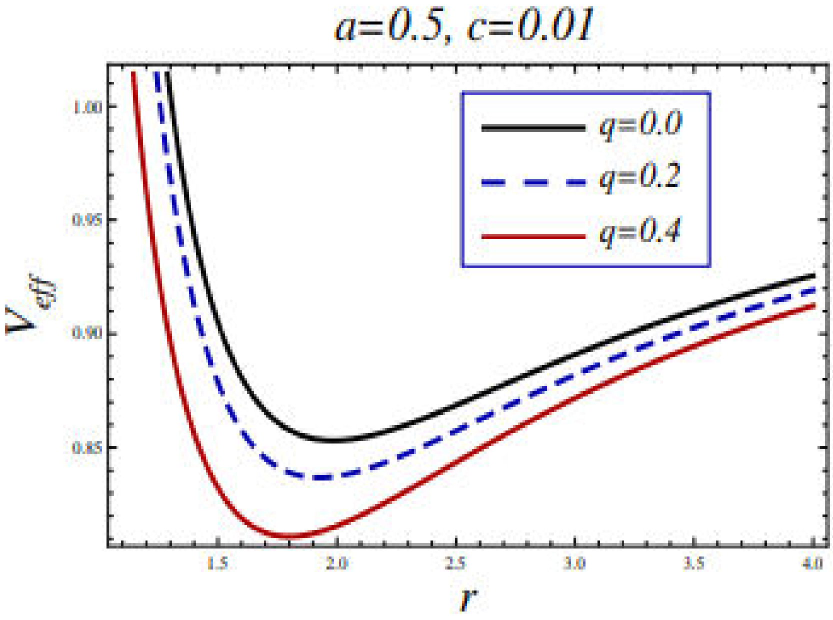

Figure 1: Plot showing the variation of effective potential with horizon r, for different values of q, a and c

$$\Sigma\frac{dt}{d\sigma} = \frac{r^2+a^2}{\Delta}\left[\mathcal{E}(r^2+a^2)-a\mathcal{L}\right]-a(a\mathcal{E}\sin^2\theta-\mathcal{L}) \qquad (10)$$

$$\Sigma\frac{dr}{d\sigma} = \pm\sqrt{\mathcal{R}}\,, \qquad (11)$$

$$\Sigma\frac{d\theta}{d\sigma} = \pm\sqrt{\Theta}\,, \qquad (12)$$

$$\Sigma\frac{d\phi}{d\sigma} = \frac{a}{\Delta}\left[\mathcal{E}(r^2+a^2)-a\mathcal{L}\right]-\left(a\mathcal{E}-\frac{\mathcal{L}}{\sin^2\theta}\right) \qquad (12)$$

Where the expressions for R(r) and Θ(θ) in Eq. (11) and (12) takes the form

$$\mathcal{R}(r) = \left[(r^2+a^2)\mathcal{E}-a\mathcal{L}\right]^2-\Delta\left[(a\mathcal{E}-\mathcal{L})^2+\mathcal{K}\right] \qquad (14)$$

$$\Theta(\theta) = \mathcal{K}-\left[\frac{\mathcal{L}^2}{\sin^2\theta}-a^2\mathcal{E}^2\right]\cos^2\theta \qquad (15)$$

Carter constant K with separability the equations (10)-(13) fully determine the behavior the picture shows a test particle orbiting a rotating charge black hole that is surrounded by quintessence These geodesic equations turn into a black hole called a Kerr Newman. when c = 0.

5.1 The black hole's shadow

The shadow of rotating charge black holes encircled by quintessence's a black hole shadow is cast by photons that fall inside the black hole. Incoming photons with smaller angular momentum fall into the black hole and form a dark circle that makes up the black hole shadow. Photons with more angular momentum turn back or scatter away from the black hole and are seen by the observer at infinity. In this case, it is only geodesics that fall to zero, which can be better defined by the coordinates of the stars, are of importance to us here α and β as

$$\alpha = \lim_{r_0\to\infty}\left(-r_0^2\sin\theta_0\frac{d\phi}{dt}\right) \qquad (16)$$

$$\beta = \lim_{r_0\to\infty} r_0^2\frac{d\theta}{dr}, \qquad (17)$$

Where r0 is the distance between the black hole and a faraway observer, and θ_0 is the angle of inclination between the black hole's z-axis and the line of sight from the source to the observer. The relationship between celestial coordinates and constants can be discovered using null geodesics equations η and ξ as

$$\alpha = -\frac{\xi}{\sin\theta} \quad (18)$$

$$\beta = \sqrt{\eta + a^2\cos^2\theta - \xi^2\cot^2\theta} \quad (19)$$

The Eqs. (18) and (19) shows how celestial coordinates are related α, β to impact parameter η and ξ.

To witness the shadow of the rotating charge black holes surrounded by quintessence, two observables must be introduced. The study of these observables is based entirely on the geometry of a black hole shadow, and it provides information about distortion. The first observable, shadow radius Rs, can be found here.

$$R_s = \frac{(\alpha_t - \alpha_r)^2 + {\beta_t}^2}{2|\alpha_t - \alpha_r|} \quad (20)$$

Where (αr, βr) is the highest point on the α-axis, and (αt , βt) is the highest point on the β-axis from which the reference circle passes (cf. Fig.2). The second observable can be described as follows:

$$\delta_s = \frac{d}{R_s}, \quad (21)$$

Where d is the distance between the black hole shadow's most left location and the reference circle (Fig. 2).

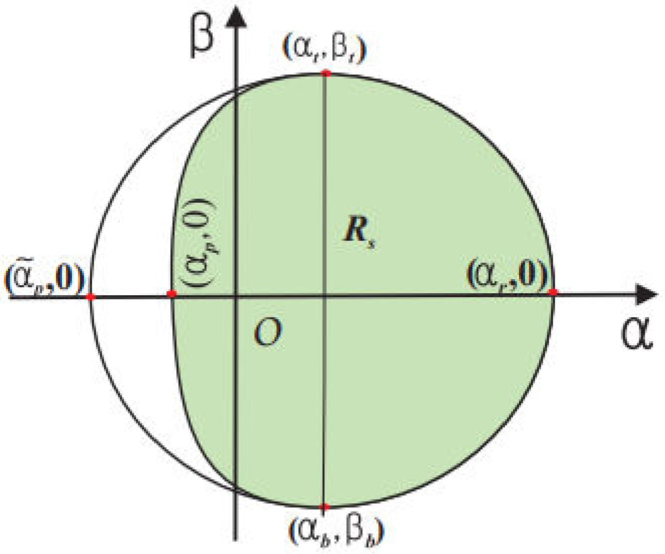

Figure 2: Schematic representation of observable Rs and δs

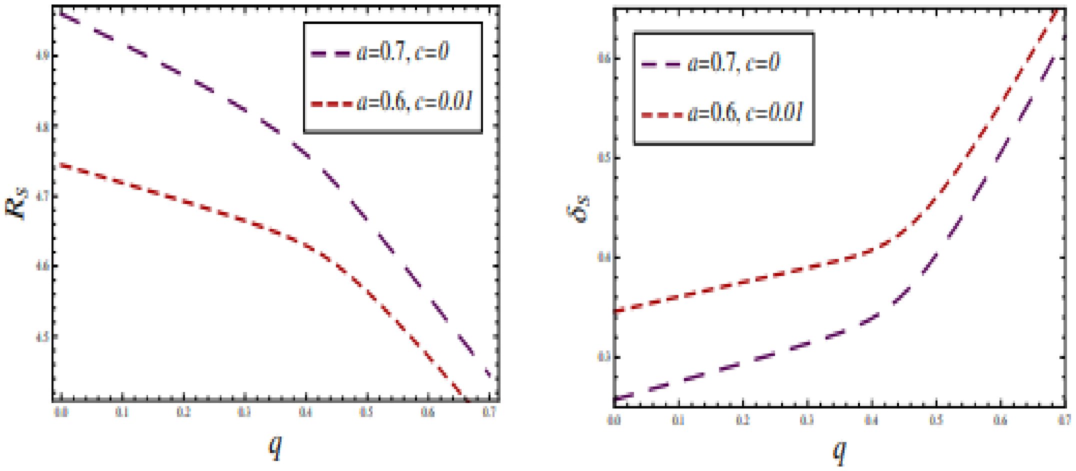

Figure 3: Plots showing the variation of radius of black hole shadow Rs and distortion parameter δs with charge q for different value of spin a

For various values of charge q, we depict the shadow radius Rs in Fig. 3. We discover that when the charge q increases, the radius of the black hole shadow shrinks. As demonstrated in Fig. 3, the distortion parameter δs grow monotonically for greater amounts of charge q.

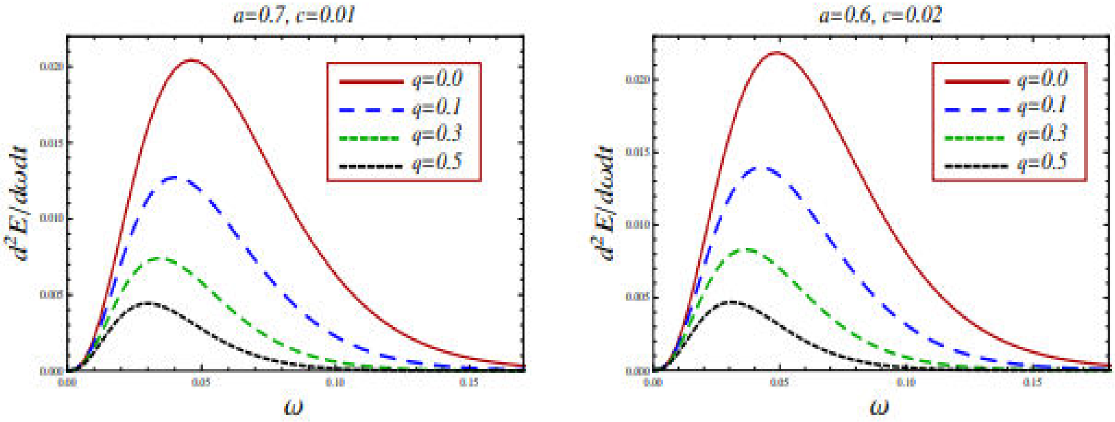

Figure 4: Plot showing the variation of energy emission rate with frequency ω for different values of q, *a* and c

With rising q and c, the size of the black hole shadow gets smaller and the distortion gets bigger. We also looked at the shadow observables Rs and s to get a better idea of the black hole's shadow, and we did that too. The rate at which the black hole emits energy has also been investigated.

6. CONCLUSION

Black holes are extremely black astronomical gravitational objects, and we must test general relativity near them in order to gain a deeper knowledge of gravity. The ability of black holes to cast shadows is an intriguing characteristic, and their direct observation can be used to test general relativity in the area of strong fields. Here, we looked at the shadows of rotating charge black holes surrounded by pure energy. We then compared our findings to those of Kerr-Newman black holes, and we found that our findings were very similar. This is what we found out during our research: The paradigmatic charge rotating black hole is a little smaller than the Kerr-Newman black hole. for fixed values of the spin parameter. We also talked about the black hole's energy output rate. The submillimeter VLBI array is working on astronomical experiments and approaches for understanding the galactic center's electromagnetic spectrum emission.

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