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STUDY OF SHADOWS OF ROTATING FIVE-DIMENSIONAL CHARGED EMCS BLACK HOLES

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Abstract

Black holes are interesting astronomical things, arguably the most entrancing articles in the Universe, and it's challenging to consider one more thing or subject that has ignited as much interest. Dark openings have been concentrated on broadly comparable to an assortment of gravity hypotheses. Late immediate perceptions, gravitational wave occasions, and the primary picture delivered by the overall Event Horizon telescope (EHT) group have reinforced such examinations. The shadow of a five-layered turning dark opening seems, by all accounts, to be somewhat more modest and less misshaped than the shadow of a four-layered Kerr dark opening. the shadow of a higher-layered Schwarschild Tangherlini dark opening, and the outcomes uncover that the size of the shadows lessens as the aspects increment. The objective of this paper is to investigate the shadow of a five-layered EMCS insignificant checked supergravity dark opening and contrast the outcomes with the Kerr dark opening/five-layered MyersPerry dark opening. We've gone over the skylines and shadows of EMCS dark openings in five aspects exhaustively, zeroing in on arrangements with equivalent size precise momenta to work on the balance of the arrangements and make the scientific investigation significantly more manageable while uncovering various captivating highlights of the dark opening shadows.

Keywords: shadow, rotating, five-dimensional, charge, EMCS, black hole, etc

1. INTRODUCTION

Black holes are interesting astronomical things, and they're probably the most interesting things in the universe. It's hard to think of another thing or subject that has gotten as much attention. However, it isn't known if or when black holes can be seen. In VLBI technology, one of the most important things is to look at the shadow of a black hole candidate called Sagittarius A, also known as Sgr A. It should be able to see the black hole down to the event horizon. Sgr A, a candidate for a black hole, casts a shadow at the centre of the galaxy because of gravitational lensing. The shape and size of this shadow can be estimated. The idea that seeing a black hole's shadow is proof that it exists is common. The shape of a shadow could be used to look at how strong the gravity is at the event horizon, as well as to see if general relativity is correct based on what we can see. There are many ways to figure out the mass and spin of a rotating black hole. You can look at the shadow of a black hole. It's interesting to look at "null geodesics," where photons from other sources flow around black holes to make a shadow. Because a black hole bends light, the event horizons make shadows on people who are far away. He took the first step toward studying a black hole shadow when he worked out the shape of a Kerr black hole's dark area, or its shadow over a light background, which he did. When you look at the Schwarzschild black hole, its shadow is a perfect circle. When you look at the Kerr black hole, its shadow is not as perfect. shadow is elongated in the direction of spin.

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1.1 String theory's shadows of 5D black holes

Black holes have been looked at a lot in terms of different gravity theories. There have been more direct observations, gravitational waves, and the first image from the Event Horizon Telescope (EHT) team, which has helped with these kinds of studies. The radius of the shadow of the core black hole is has been calculated based on this observation (42±3)μas with a ten percent deviation from circularity This yields an estimate of the central mass, which is given by $M=(6.5\pm0.7)\times10^9 M_\odot$, General Relativity, according to Einstein (GR). These and other measurements could help us see into the strong gravity regime and choose between different theories. The shadow of a black hole is just a two-dimensional dark area on the celestial sphere that is caused by a lot of gravitational lensing of light around these small, dense things. Shape and size of the shadow are determined by the shape and size of the space-time in which black holes live which is regulated by a number of characteristics. Such observational data can reveal important details about black hole space-time and the gravity theory that governs it. Several papers have addressed the shadows of various black holes using relevant techniques and approaches in this context. The interaction between the black hole's quasi-normal modes and its shadow has been studied in particular.

Different methodologies and methods, including numerical ones, have been used to study the thermodynamically and in terms of other optical characteristics of black holes in 4D and any other dimension. As an example, some research has looked at the relationship between Black Holes and Negative Cosmological and thermodynamical Models (AdS) geometries. It has been shown that RN-AdS black holes behave in a similar way to Van der Waals fluids because they have a lot of pressure and a lot of volume. It has been found that PV criticality is linked to liquid-gas statistical systems. It has also been used to look into these kinds of things. In addition, black hole objects that live in higher dimensions have been looked at, which means they need a lot of rotating parameters because of space-time symmetries. Non-trivial extended compact objects, which go beyond black holes and are backed by brain physics, are found in some places can also emerge in such environments. Alternative methods were used to obtain and investigate the associated horizon geometries.

2. LITERATURE REVIEW

Contreras, Ernesto & Rincon, Angel & Panotopoulos, Grigorios & Bargueño, Pedro (2021) we investigate the geodesics and black hole shadow of a general non–extremal five dimensional black hole are caused by the fact that higher dimensional theories expect black holes that are different from their four dimensional counterparts to be present. The system in question is the Chong–Cveti–Lü–Pope system. It has the Myers–Perry black hole as a limit, which means it can't go any further than that.

Tao Zhu, Qiang Wu, Mubasher Jamil, and Kimet Jusufi (2019) the shadows cast by two types of charged and slow-moving black holes in Einstein's Aether theory of gravity are looked at in this study. For the first type, the aether coupling constants c14 and c123 both equal zero. For the second, the aether coupling constants are both zero, but c14 is 0. It can be bigger or smaller because of both the black hole's mass and charge, as well as the presence of the aether field. First, the size of the first type of black hole's shadow grows with the parameter c13. The second type of black hole's shadow grows with the parameter c14. c13 but reduces with the parameter c14. Using the data from the Event

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Horizon Telescope's first black hole image, we examine the observational limits on these a ether parameters. Using the Gauss-Bonnet theorem, We also look into how the an ether field affects the deflection angle of light and how long it takes for it to get there. The aether parameter c13 in the first order has been shown to have a small effect on the deflection angle and time delay for a specific combination c123 = 0.

Rajibul, Shaikh (2018) we investigate the shadows cast by a certain type of rotating wormholes, emphasizing the critical function of the rotating wormhole throat in the production of a shadow, a feature that has been overlooked in previous research on the same class of rotating wormhole shadows, resulting in erroneous conclusions. We investigate how the shadows are affected by the wormholes' spin. Our findings are compared to those of the Kerr black hole. The shapes of the wormhole shadows begin to deviate significantly from those of the black hole as the spin value increases. If future observations reveal such a large variance, it could imply the presence of a wormhole. In other words, the findings show that the wormholes considered in this study and having an acceptable spin may be separated from a black hole by observing their shadows.

Muhammed Amir, Balendra Singh, and Sushant Ghosh (2017) a black hole shadow is a dark area that is made by photons falling into the black hole in a certain way. Revolving five-dimensional EMCS black holes have shadows that are defined by three factors: mass (M), spin (a), and charge (q). The shape of the shadows is determined by these three factors. The charge q and the spin a both affect the size of the black hole shadow. When we look at the Myers-Perry black hole, we show that the size of the shadow always gets smaller as the charge q goes up.increases for a given value of a. We also calculate the distortion caused by the black hole's spin; curiously, distortion grows as charge q increases. We explore naked singularity scenarios and demonstrate how parameters q and a affect the shadow of naked singularity.

3. OBJECTIVES

- To study String theory's shadows of 5D black holes.
- To investigate rotating five-dimensional EMCS black holes and shadow.

4. FIVE-DIMENSIONAL EMCS BLACK HOLES ROTATING

When the Chern-Simons coefficient is used as a parameter, EMCS (Einstein, Maxwell, Chern, and Simons) theory says that stationary black holes have some very interesting properties. The EMCS black hole solutions in five dimensions that are asymptotically flat are briefly talked about. For the bosonic part of the minimal five-dimensional supergravity, this is the Lagrangian.

$$\mathcal{L} = \frac{1}{16\pi}\left[\sqrt{-g}(R-F^2) - \frac{2}{3\sqrt{3}}\epsilon^{\mu\nu\rho\sigma\tau}A_\mu F_{\nu\rho}F_{\sigma\tau}\right] \quad (1)$$

Where R is the curvature scalar, $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$ with Aμ is the gauge potential, and $\in^{\mu\nu\lambda\rho\sigma}$ is the five-dimensional Levi-Civita tensor. In addition to the Einstein-Maxwell term, the Lagrangian (1) incorporates an additional Chern-Simons term. The appropriate equations of motion:

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$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = 2\left(F_{\mu\alpha}F_{\nu\alpha} - \frac{1}{4}g_{\mu\nu}F_{\rho\sigma}F^{\rho\sigma}\right),$$
$$\nabla_\mu\left(F^{\mu\nu} + \frac{1}{\sqrt{3}\sqrt{-g}}\epsilon^{\mu\nu\lambda\rho\sigma}A_\lambda F_{\rho\sigma}\right) = 0. \quad (2)$$

The metric can be used to define a five-dimensional rotating EMCS black hole solution in Boyer-Lindquist coordinates (t, r, θ, φ, ψ)

$$\begin{aligned} ds^2 &= -\frac{\rho^2 dt^2 + 2q\nu dt}{\rho^2} + \frac{2q\nu\omega}{\rho^2} + \frac{\mu\rho^2 - q^2}{\rho^4}(dt-\omega)^2 \\ &+\frac{\rho^2 dx^2}{4\Delta} + \rho^2 d\theta^2 + \left(x+a^2\right)\sin^2\theta d\phi^2 \\ &+\left(x+b^2\right)\cos^2\theta d\psi^2, \end{aligned} \quad (3)$$

Where

$$\Delta = (x + a^2)(x + b^2) + q^2 + 2abq - \mu x,$$

$$\rho^2 = x + a^2 \cos^2\theta + b^2 \sin^2\theta,$$

$$\nu = b \sin^2\theta\, d\emptyset + a \cos^2\theta d\psi,$$

$$\omega = a \sin^2\theta d\emptyset + b \cos^2\theta d\psi \quad (4)$$

And the metric's gauge potential (3) can be stated as

$$A_\mu dx^\mu = \frac{\sqrt{3}\,q}{\rho^2}(dt-\omega) \quad (5)$$

It has a mass of. The black hole's charge is q. The black hole's angular momenta are a and b, which are different. Then, too, the fact is that the metric's non-zero components (3) can be written as

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$$
\begin{aligned}
g_{tt} &= \frac{\rho^2(\mu-\rho^2)-q^2}{\rho^4}, \\
g_{t\phi} &= -\frac{a(\mu\rho^2-q^2)+bq\rho^2\sin^2\theta}{\rho^4}, \\
g_{t\psi} &= -\frac{b(\mu\rho^2-q^2)+aq\rho^2\cos^2\theta}{\rho^4}, \\
g_{\phi\psi} &= \frac{[ab(\mu\rho^2-q^2)+(a^2+b^2)q\rho^2]\sin^2\theta\cos^2\theta}{\rho^4}, \\
g_{xx} &= \frac{\rho^2}{\Delta}, \qquad g_{\theta\theta}=\rho^2, \\
g_{\phi\phi} &= (x+a^2)\sin^2\theta+\frac{a[a(\mu\rho^2-q^2)+2bq\rho^2]\sin^4\theta}{\rho^4}, \\
g_{\psi\psi} &= (x+b^2)\cos^2\theta+\frac{b[b(\mu\rho^2-q^2)+2aq\rho^2]\cos^4\theta}{\rho^4}.
\end{aligned} \tag{6}
$$

$x = r^2$ has been used to change the radial coordinate to a new radial coordinate, x, as shown in the figure. One of the black holes that is being looked at is the five-dimensional EMCS black hole, which reduces to the five-dimensional Myers-Perry black hole if $q = 0$. If $a = 0$, it reduces to the five-dimensional Schwarschild-Tangherlini black hole, which is also being looked at. Because the metric (3) doesn't change when you add or subtract from it, there can be three Killing vectors that can be used.

$$
\ell = \frac{\partial}{\partial t}+\Omega_a\frac{\partial}{\partial\phi}+\Omega_b\frac{\partial}{\partial\psi}, \tag{7}
$$

At the event horizon, these Killing vectors become null. For the metric (3), the angular velocities are as follows:

$$
\begin{aligned}
\Omega_a &= \frac{a(x_+^H+b^2)+bq}{(x_+^H+a^2)(x_+^H+b^2)+abq}, \\
\Omega_b &= \frac{b(x_+^H+a^2)+aq}{(x_+^H+a^2)(x_+^H+b^2)+abq},
\end{aligned} \tag{8}
$$

The event horizon of a five-dimensional EMCS black hole is denoted as x^H_+. The EMCS black hole's surface gravity (3) is calculated as follows:

$$
\kappa = \frac{(x_+^H)^2-(ab+q)^2}{\sqrt{x_+^H}[(x_+^H+a^2)(x_+^H+b^2)+abq]}. \tag{9}
$$

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EMCS black holes follow the first rule of thermodynamics. The Hawking temperature of EMCS black holes is the same as that of a five-dimensional EMCS black hole may be simply determined using T = κ/(2π) and surface gravity (3.9). The entropy of a black hole is calculated as.

$$S = \frac{\pi^2[(x_+^H + a^2)(x_+^H + b^2) + abq]}{2\sqrt{x_+^H}}, \quad (10)$$

When a = b = 0 = q, it decreases to

$$S = \frac{\pi^2(x_+^H)^{3/2}}{2} \quad (11)$$

The Komar integral interprets

$$J = \frac{1}{16\pi}\int_{S^3} *dK, \quad (12)$$

Where K = ∂/∂ϕ or K = ∂/∂ψ, yielding

$$J_a = \frac{\pi(\mu a + qb)}{4}, \quad J_b = \frac{\pi(\mu b + qa)}{4} \quad (13)$$

The Gaussian integral can be used to compute the electric charge.

$$Q = \frac{1}{16\pi}\int_{S^3}(*F - F \wedge A/\sqrt{3}), \quad (14)$$

This gives

$$Q = \frac{\sqrt{3}\,\pi q}{4}. \quad (15)$$

As is generally known, the first law of thermodynamics applies to the five-dimensional EMCS blackhole, therefore the conserved mass or energy can be computed by integrating.

$$dE = T\,dS + \Omega_a dJ_a + \Omega_b dJ_b + \Phi dQ, \quad (16)$$

Where Φ is the electrostatic potential and is the electrostatic potential. Using Eq. (16), we arrive at

$$E = \frac{3\pi\mu}{8} \quad (17)$$

Which is the EMCS black hole's preserved energy in five dimensions surprisingly, the determinant is identical in the charged and uncharged cases $\sqrt{-\det g} = \rho^2 \sin\theta \cos\theta/2$.

5. EMCS BLACK HOLE SHADOW IN FIVE DIMENSIONS

Higher dimensions allow for the creation of supermassive black holes are a type of astrophysical object that is different from a normal black hole. General relativity doesn't have the same gravitational lensing properties as other gravity theories with extra dimensions. The gravitational field in supermassive black holes may be different from the one in general relativity, so a number of tests have been proposed to look for signs of extra dimensions in these types of places. It was shown, for example, how shadow measurements can help us learn more about black hole properties that are higher-dimensional. Observers see light being deflected by the black hole's gravitational field when it is in between them and a bright object. Some photons emitted by the bright object fall into the black hole, and the observer doesn't see them. This is because the black hole takes some of these photons away. A black hole has three ways for photons to get there: fall into the black hole or scatter away from it. The third option is critical geodesics, which are circular orbits around the black hole that have a critical radius. Unstable orbits with a constant radius (r = 3M for the Schwarzschild black hole) are what these things are known as. These are what make the black hole's shadow look like it has a shape. A black hole looks like this because we use celestial coordinates, which can be found by finding the orthonormal basis vectors for the person who is looking at it.

$$\begin{aligned} e_{\hat{t}} &= \lambda e_t + \varsigma e_\phi + \chi e_\psi, \\ e_{\hat{r}} &= \frac{1}{\sqrt{g_{rr}}} e_r, \quad e_{\hat{\theta}} = \frac{1}{\sqrt{g_{\theta\theta}}} e_\theta, \\ e_{\hat{\phi}} &= \frac{1}{\sqrt{g_{\phi\phi}}} e_\phi, \quad e_{\hat{\psi}} = \frac{1}{\sqrt{g_{\psi\psi}}} e_\psi, \end{aligned} \tag{17}$$

Where λ, ς and χ are chosen in such a way that the local basis vectors are orthogonal

The nonrotating five-dimensional EMCS black hole is a type of five-dimensional Reissner-Nordstr om black hole whose shadow is a complete circle with radius R_s (Fig. 1). For various values of charge q, we plotted the shadow of a nonrotating five-dimensional EMCS black hole. The influence of charge q on the radius of the circle may be seen as q increases (Fig. 1). The radius of the shadow at q = 0 is $R_s = 2$, which is identical to the Schwarzschild black hole in five dimensions. As a result, charge q has the effect of reducing the size of the shadow (Fig. 1). The behaviour of the black hole shadow in the presence of spin$a$, charge q, and extra dimension is next examined in the rotating situation of the five-dimensional EMCS black hole. As a grows larger, the shadow becomes increasingly deformed and shifts to the right on the vertical axis, as seen in the Kerr case. In the absence of charge, one obtains q = 0.

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$$\alpha^2+\beta^2 = \frac{(x+a^2)\left[2a^4+x(-5+6x)+a^2(1+8x)\right]+2\left(x-(x+a^2)^2\right)\sqrt{2(x+a^2)}}{(-1+2a^2+2x)^2}+a^2. \quad (18)$$

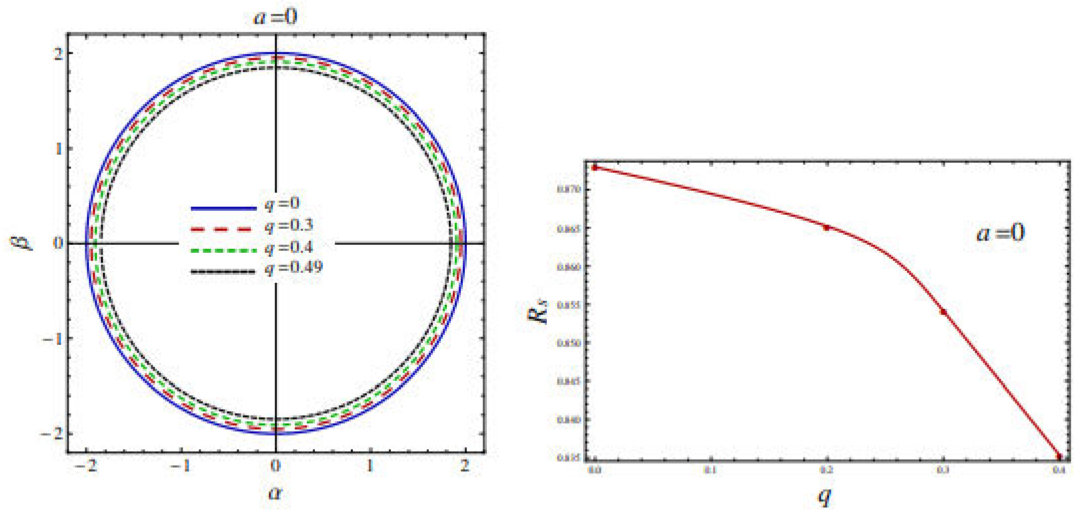

Figure 1: Plot showing the shapes of black hole shadow cast by EMCS black hole with inclination angle $\theta_0 = \pi/2$ and corresponding observable R_s, for different values of charge q for the non-rotating case (a = 0)

For various values of charge q and spin a, the morphologies of shadow for the five-dimensional EMCS black hole have been presented in Fig. 2. Instead of being a perfect circle, the shadow of a black hole is a distorted circle. The factors a, q, and extra dimension have a significant impact on the shape of the shadow. With increasing q, the size of the shadow shrinks continually (Fig. 2). This can be seen as a dragging effect caused by the black hole's rotation. The extra dimension has the same effect on the shadow's size.

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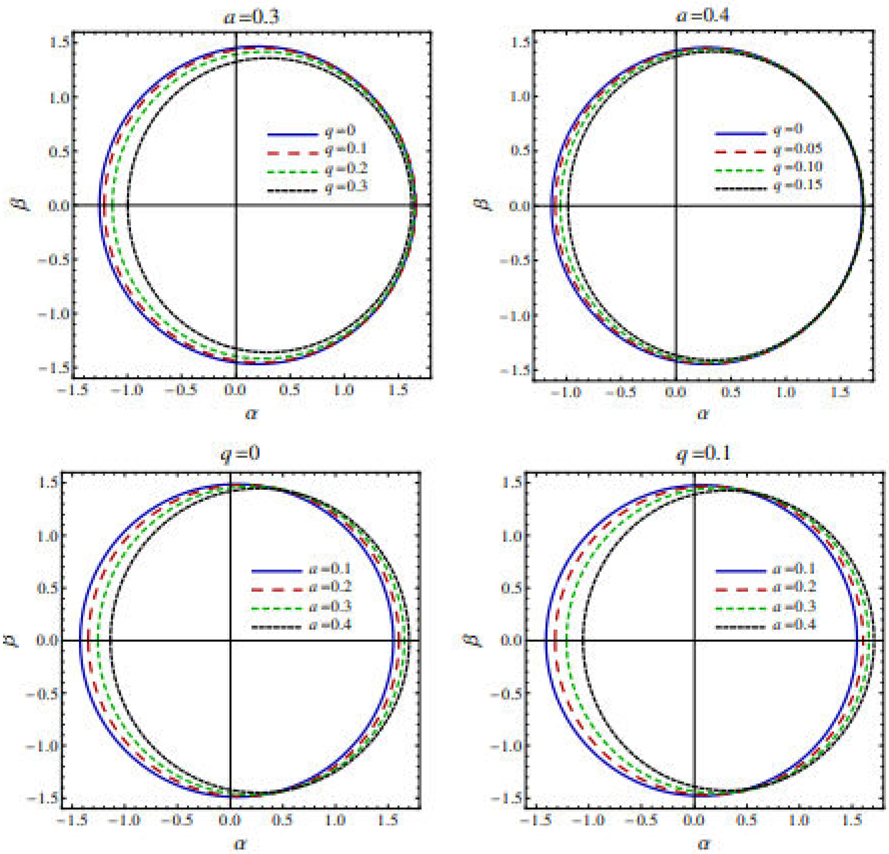

Figure 2: Plot showing the shapes of shadows cast by five-dimensional EMCS black hole with inclination angle $\theta_0 = \pi/2$ for different values of charge q and spin a with case q = 0 referring to Myers-Perry black hole

Due to the prospect of detecting the photos of the black hole that is so big. Sgr A is at the centre of our galaxy, and a lot of people are interested in how a strong gravitational field near a black hole makes a shadow. For a five-dimensional EMCS black hole, we looked into the shadow of a black hole and came up with analytical formulas for the photon areas. When we look at a rotating five-dimensional black hole with EMCS, we also do some math to figure out how big and how big its shadow is.

6. CONCLUSION

The goal of this paper is to look into the shadow of a five-dimensional EMCS minimal gauged supergravity black hole and compare it to the Kerr black hole and the five-dimensional MyersPerry black hole. Myers-Perry black holes have five dimensions. EMCS black holes have an extra charge parameter called q, which makes them different from Myers-Perry black holes. EMCS black holes have more complicated horizons and ergospheres than other types of black holes. Note that the size of the ergosphere changes with both its charge q and its rotational parameter a, so it's important to keep this in mind. Rotating five-dimensional EMCS black's shadow is darker than the shadow of a rotating five-dimensional EMCS black, but the shadow of a rotating five-dimensional EMCS black has a more distorted circle on top of the dark zone

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