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STUDY THE BEHAVIOUR OF NON-SPINNING BLACK HOLE ON LIGHT PARTICLES

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ABSTRACT

A Black hole is a massive object whose gravity is so strong that nothing can escape from it, not even light. To better understand this we can considered the concept of escape velocity. The concept of escape velocity gives us a clear and intuitive way of thinking about Black holes but unfortunately does not provide full description of the Physics behind these objects. Current Technologies have enabled glimpses at the many facets of black holes, which we know to be plentiful in our Cosmos. In this paper we are going to derive a formula for gravitational force acting between the black hole (non spinning) and light particles passing near the radius of event horizon of black holes.

KEYWORDS- BLACK HOLES, COSMOS, EVENT HORIZON, GRAVITY

INTRODUCTION

Black holes are the bits of space and time, it is a region of space-time exhibiting such strong gravitational effects that nothing, not even particles and electromagnetic radiation such as light can escape from inside it. According to the general theory of relativity a sufficiently compact mass can deform space time to form a black hole. The boundary of the region from which no escape is possible is called the event horizon. Although the event horizon has an enormous effect on the fate and circumstances of an object crossing it, no locally detectable features appear to be observed.

The first modern solution of general relativity that would characterize a black hole was found by Karl Schwarzschild in 1916, although its interpretation as a region of space from which nothing can escape was first published by David Finkelstein in 1958. Black holes were long considered a mathematical curiosity; it was during the 1960s that theoretical work showed they were a generic prediction of general relativity.

The presence of a black hole can be inferred through its interaction with other matter and with electromagnetic radiation such as visible light. Matter that falls into a black hole can form an external accretion disk heated by friction, forming some of the brightest objects in the universe. In this paper we try to give an overview about the behaviour of Black hole on light particles.

TYPES OF BLACK HOLES-

There are two types of black holes-

1. **Schwarzschild or Non-spinning black hole:** The **Schwarzschild** black hole is the simplest black hole, in which the core does not rotate. This type of black hole only has a singularity and an event horizon.
2. **Kerr or spinning black hole:** The kerr Black hole probably the most common form in nature, rotates because the star from which it was formed was rotating. When the rotating star collapses, the core continuous to rotate, and this carried over to the Black hole(conservation of angular momentum). The kerr Black hole has the following parts:
    - **Singularity-** The collapsed core.
    - **Event horizon-** The opening of the hole.
    - **Ergosphere-** An egged shaped region of distorted space around the event horizon (the distortion is caused by the spinning of the Black hole, which drags the space around it).
    - **Static limit-** The boundary between the ergosphere and normal space.

FORMATION OF A BLACK HOLE

A common type of black hole is produced by certain dying stars. A star with a mass greater than about 20 times the mass of our Sun may produce a black hole at the end of its life.

In the normal life of a star there is a constant tug of war between gravity pulling in and the degenerate pressure pushing out. Nuclear reactions in the core of the star produce enough energy and pressure to push outward. For most of a star's life, gravity and pressure balance each other exactly, and so the star is stable. However, when a star runs out of nuclear fuel, gravity gets the upper hand and the material in the core is compressed even further. The more massive the core of the star, the greater the force of gravity that compresses the material, collapsing it under its own weight.

For small stars, when the nuclear fuel is exhausted and there are no more nuclear reactions to fight gravity, the repulsive forces among electrons within the star eventually create enough pressure to halt further gravitational collapse. The star then cools and dies peacefully. This type of star is called a "white dwarf."

When a very massive star exhausts its nuclear fuel it explodes as a supernova. The outer parts of the star are expelled violently into space, while the core completely collapses under its own weight.

If the core remaining after the supernova is very massive ($> 2.5M_{\odot}$, where $M_{\odot}$ is the mass of the Sun), no known repulsive force inside a star can push back hard enough to prevent gravity from completely collapsing the core into a black hole.

From the perspective of the collapsing star, the core compacts into a mathematical point with virtually zero volume, where it is said to have infinite density. This is called a singularity.

Where this happens, it would require a velocity greater than the speed of light to escape the object's gravity. Since no object can reach a speed faster than light, no matter or radiation can escape. Anything, including light, that passes within event horizon is trapped forever.

By absorbing other stars and merging with other black holes, super massive black holes of millions of solar masses ($M_{\odot}$) may form, i.e., super massive are abundant in our universe. It is believe that a super massive Black hole is at the centre of our own Milky way galaxy, and the other galaxies around us.

CALCULATIONS

From Newton's law of gravity we know

$$F=G\,\frac{m_1 m_2}{r^2} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

Where m_1 & m_2 are the mass of any two bodies in universe, r is the distance between them and G is gravitational constant, and F is the force of attraction between m_1 & m_2.

Using this law, we can calculate the force of attraction between black holes and light particles.

So we have,

$$F=G\,\frac{Mm}{R^2} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ (2)$$

Where M and R be the mass and radius of event horizon of Black holes, and m is the mass of light particle.

The mass-energy equivalence relation can be applied with the mass of light particle, and we have,

$$E=mC^2 \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots...(3)$$

$$\text{Or} \quad m= E/C^2 \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

Again according to quantum theory

$$E=h\upsilon\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5)$$

Therefore, $$m= \frac{h\upsilon}{C^2} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (6)$$

$$\text{Or } m= \frac{h}{C\lambda} \quad [\text{ since } \upsilon = c\lambda] \;\ldots\ldots\ldots\ldots\ldots..(7)$$

Therefore from eqn. (2) we get $$F = \frac{GMh}{C\lambda R^2} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(8)$$

The black hole possesses an event horizon which casually isolates the inside of the Black hole from the rest of the universe.

The radius of the event horizon of a non spinning Black hole given by the Schwarzschild radius as

$$R = \frac{2GM}{C^2} \text{ ……………………………….. (9)}$$

The radius of the spinning Black hole is

$$R' = \frac{GM}{C^2} \text{ ………………………………..(10)}$$

Putting this values in eqn. (8) we get

$$F = \frac{hC^3}{4GM\lambda} \text{ and } F' = \frac{hC^3}{GM\lambda} \text{ ……………………….. (11)}$$

This is the expression of gravitational force acting on light particles due to non spinning and spinning Black holes.

Here Planck's constant represents the law of quantum world. The speed of light (C) is the cornerstone of the special theory of relativity. But Newton's gravitational constant G has a new meaning. According to Einstein, G determines the degree to which a given distribution of matter warps space and time. So in new conception, space time was no longer a spectator of events, but itself a dynamical participant that changed in response to the amount of matter present. So this form a curvature of space time, which according to the Einstein is the origin of gravity.

Now, for convenience, let G=h=C=1, so eqn. (11) becomes

$$F = \frac{1}{4M\lambda} \text{ ……………………(12)}$$

$$\text{And } F' = \frac{1}{M\lambda} \text{ ………………………(13)}$$

Again, if k is the surface gravity of Black holes, then

$$k = \frac{1}{4M} \text{ ……………………………..(14)}$$

Therefore, Eqn. (12), & (13) becomes

$$F = \frac{k}{\lambda} \text{ ……………………………(15)}$$

$$\text{And } F' = \frac{4k}{\lambda} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(16)$$

As surface gravity (k) of a black hole is constant on horizon, so we can write-

$$F \propto \frac{1}{\lambda} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(17)$$

This relation shows that the force of attraction acting between Black hole and light particle is inversely proportional to the wavelength of Electromagnetic wave coming towards the event horizon of Black holes. Hence the radiation of longer wavelength is attracted more lesser than that of others.

DISCUSSION

In this previous calculation we have shown a relation between gravitational force acting between the black hole (non spinning) and light particle passing near the radius of event horizon of black holes by applying Newton's laws of gravitation with the mass energy equivalance relation and Quantum theory of radiation.

To know the nature of gravitational force acting between the light particle and the Blackhole we use X-ray binaries (XRBs) data of different test non-spinning Blackholes (Table-1), and plot a graph between the gravitational force acting between the Blackhole and light particles, to the radius of event horizon (R_{BH}) of different test non- spinning Black holes(fig-1).

Table1-

*Mass of the sun (M_Θ) = 1.99×10^{30} kg

Sl. No.	Mass of BHs (M)	R_{BH}= 2950 (M/M_Θ) meter	Wave length (m)	Gravitational force (N)
1	$1x10^6$ M_Θ	$0.0295X10^{11}$	555 $x10^{-9,}$	226.3570 X 10^{33}
2	$2x10^6$ M_Θ	0.0595 X 10^{11}	555 $x10^{-9,}$	113.1785 X 10^{33}
3	$3x10^6$ M_Θ	0.0885 X 10^{11}	555 $x10^{-9,}$	75.4523 X 10^{33}
4	$4x10^6$ M_Θ	0.1180 X 10^{11}	555 $x10^{-9,}$	56.5892 X 10^{33}
5	$5x10^6$ M_Θ	0.1475 X 10^{11}	555 $x10^{-9,}$	45.2714 X 10^{33}
6	$6x10^6$ M_Θ	0.1770 X 10^{11}	555 $x10^{-9,}$	37.7261 X 10^{33}
7	$7x10^6$ M_Θ	0.2065 X 10^{11}	555 $x10^{-9,}$	32.3367 X 10^{33}
8	$8x10^6$ M_Θ	0.2360 X 10^{11}	555 $x10^{-9,}$	28.2946 X 10^{33}
9	$9x10^6$ M_Θ	0.2655 X 10^{11}	555 $x10^{-9,}$	25.1508 X 10^{33}
10	$1x10^7$ M_Θ	0.2950 X 10^{11}	555 $x10^{-9,}$	22.6357 X 10^{33}

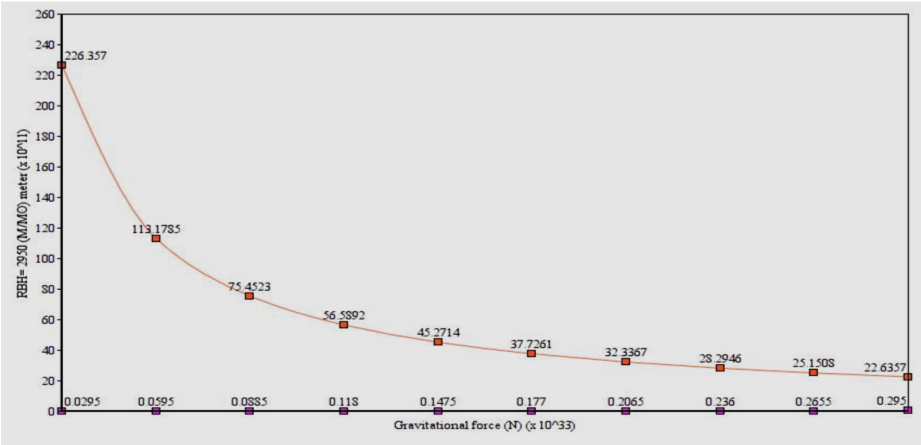

FIG-1: GRAVITATIONAL FORCE BETWEEN THE DIFFERENT BLACK HOLES AND LIGHT PARTICLES, TO THE RADIUS OF EVENT HORIZON (R_{BH}) OF DIFFERENT TEST NON-SPINNING BLACK HOLES GRAPH IN XRB_S

The above graph shows that gravitational pull between the light particle and the Black hole increases with the decrease of the radius of event horizon.

CONCLUSIONS

After going through all this work and calculations, we can draw some conclusions. If we assume the surface gravity is constant, then the gravitational force between the Black holes and the light particles are inversely proportional to the wavelength of radiation. So the light waves of shorter wavelength has attracted more than that of longer wavelength for constant surface gravity. Here we should remember that these calculations are only made for non spinning Black holes. For maximally spinning Black holes the surface gravity becomes zero. So for that case we shall calculate the force of attraction between Black hole and light particles by using mass of different test non-spinning and spinning Black holes.

REFERENCES:

1. Dipo Mahto, Md Shams Nadeem, Mahendra Ram, and Kumari Vineeta, "*Gravitational Force between the Black Hole and Light Particle in XRBs" , Journal of Gravity, Volume 2013, Article ID 232676,*
2. Prajval Shastri , "*Black Holes in Our Universe*"
3. Ryan C. Hickox, "*super massive Black holes and the growth of galaxies*"
4. D. D. Mario, "*The black hole electron," Journal of Theoretics, 2000.*

5. S. Weinberg, "*Gravitation and Cosmology: Principles and Applications of General Theory of Relativity", Wiley, 1972.*
6. R. Narayan, "*Black holes in astrophysics," New Journal of Physics, vol. 7, article 199, 2005.*
7. Mella, Fulvio, 2003, *The Black Hole at the Center of Our Galaxy, Princeton University Press*.
8. Shapiro, Stuart L. & Teukolsky, Saul A. *1994, Black Holes, White Dwarfs, and Neutron Stars: The Physics of Compact Objects, Wiley*
9. Penrose, R. (2002). "*Gravitational Collapse: The Role of General Relativity". General Relativity and Gravitation.*
10. "*Beyond-Einstein from the Big Bang to Black Holes*", prepared by (*The Structure and Evolution of the Universe Roadmap Team),* (Jan 2003)
11. Hawking, Stephen (1988). *A Brief History of Time. Bantam Books. ISBN 0-553-38016-8.*
12. T. Hooft, G. (2009). "*Introduction to the Theory of Black Holes"*
13. "*Introduction to Black Holes". Retrieved 2017-09-26.*
14. M. Volonteri "*The Formation and Evolution of Massive Black Holes"*
15. https://www.nasa.gov/audience/forstudents/k-4/stories/nasa-knows/what-is-a-black-hole-k4.html
16. http://hubblesite.org/reference_desk/faq/answer.php.id=56&cat=exotic
17. https://www.space.com/15421-black-holes-facts-formation-discovery-sdcmp.html
18. http://amazingspace.org/resources/explorations/blackholes/lesson/whatisit/types.html