Journal of Cosmology, Vol. 26, No. 22, pp 15153 - 15183

ANTIMATTER BLACK HOLES

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ABSTRACT

We propose an alternative gravity model to the theory of general relativity, in which the spacetime curvature would be modified by the interaction of matter and antimatter virtual particles, both interacting with each other and with matter through fractal sublevels of the quantum vacuum, creating a sequence of gravitational shielding and anti-shielding effects. The equations of planetary motion based on the Schwarzschild metric and its variables would be modified, as would current theories about black holes which would be made of antimatter.

Key Words

Fractal sublevels of the quantum vacuum, vector charges, virtual particles, modified Schwarzschild metric, equations of planetary motion, perihelion of Mercury, antimatter black holes.

1. INTRODUCTION

Before addressing general relativity, we will approach Newtonian mechanics as a borderline case. Since gravity is the subject of this study, we will consider a mass where the electrostatic forces annul each other due to the equal number of protons and electrons in atoms or molecules. The strong force is annulled in the nucleus of the atom, leaving gravity as a residual force from a mass because real particles of antimatter neutralizing it are not found.

As an example, let's analyze the fractal process of an elementary particle, such as the electron. The electron attracts virtual positrons of antimatter from the quantum vacuum, and these attenuate its negative charge, an experimentally verified effect. In previous publications [1], we postulated the existence of sublevels of the quantum vacuum. They would be composed of virtual electrons from a second level of the quantum vacuum which, in turn, would be attracted by the virtual positrons of a first level, thus attenuating their effect. Likewise, these virtual electrons would attract virtual positrons of a third level which would also attenuate their effect. This process of interactions would continue indefinitely in a convergent, infinite, fractal sequence, neutralizing the charge of the electron at a null distance.

Figure 1 is a graphic representation of this process. The electron's real particle is represented by a large red sphere. The virtual positrons of the first level of the quantum vacuum are represented by smaller blue spheres around the electron. The virtual electrons of the second level are represented by smaller red spheres around the virtual positrons. The sequence continues indefinitely in a fractal mode.

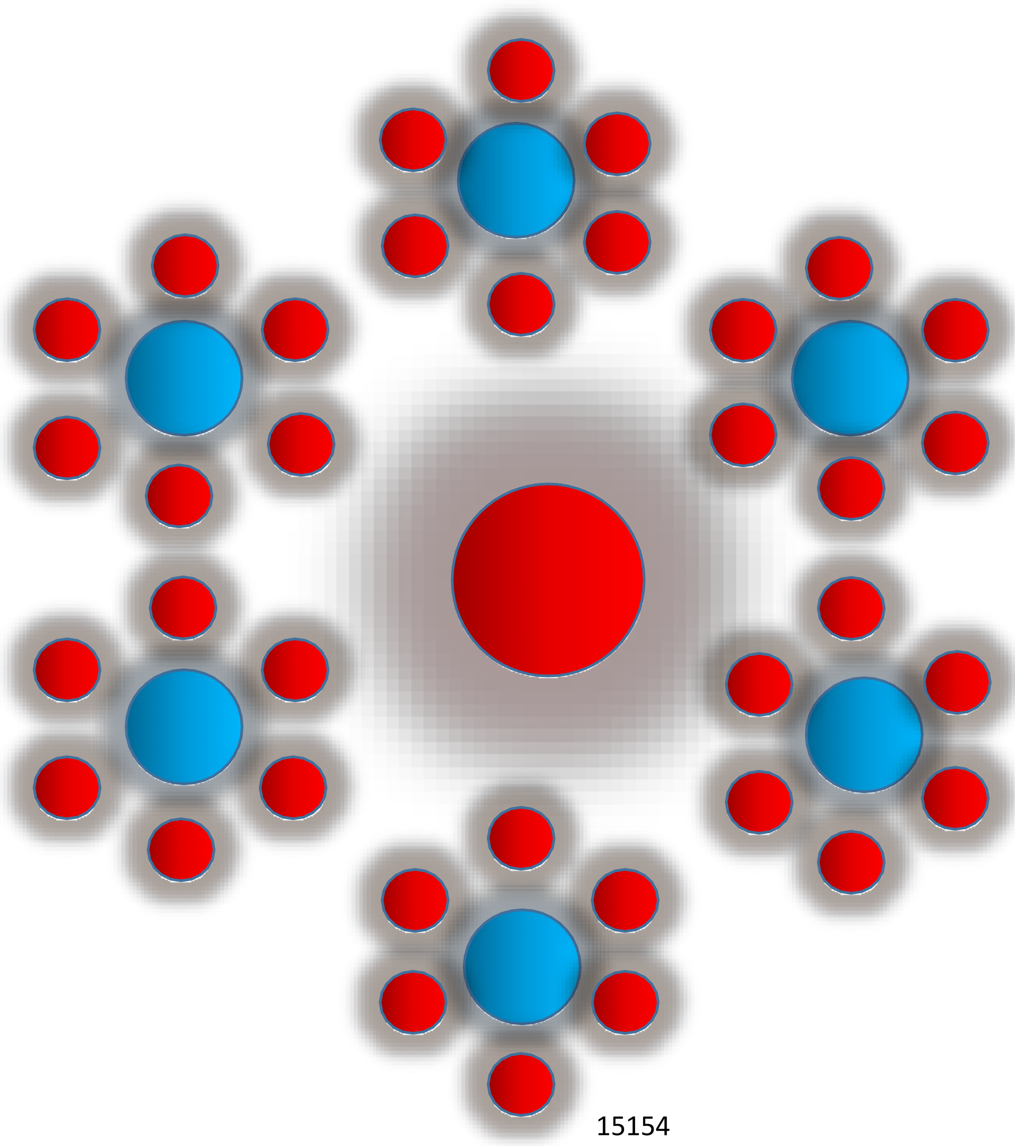

Figure 1. A visual representation of the interaction process of virtual matter and antimatter particles in the sub-levels of the quantum vacuum.

The equation that we found and which defines the intensity E of the electric charge would be given by [2]:

$$E = \frac{e^{-}}{4\pi\epsilon_0 r^2} e^{-\frac{\alpha\hbar}{m_e c r}} \tag{1.1}$$

Where e^{-} is the charge of the electron, ϵ_0 is the constant of permittivity in the vacuum, r is the distance to the electron, α is the cosmological constant, $\hbar$ is the reduced Planck constant, m_e is the electron mass and c is the speed of light in the vacuum.

Figure 2 represents the graph of the intensity E for $\alpha\hbar/m_e c = 1$, which would explain why (without the need to resort to renormalization) the electron - as a point particle- does not explode under the effect of its own repulsive charge. The area enclosed by this curve represents the energy of the electron. The same would also occur with the quarks [3]. In this case (as it is shown in the graph), for short distances, intensity increases with distance, which is precisely what happens with quarks. This would explain the confinement of these particles and their asymptotic freedom.

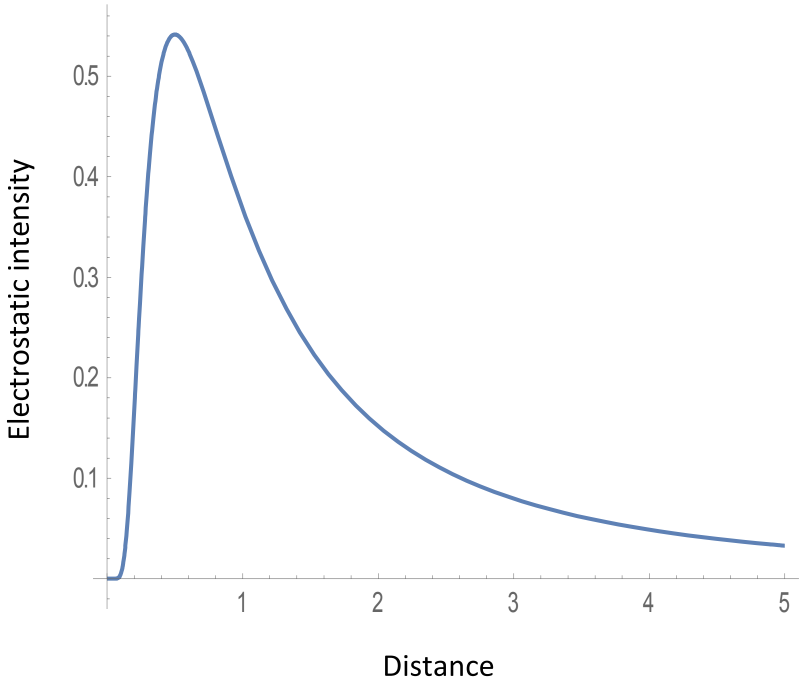

Figure 2. Graphic representation of the electrostatic intensity of the electron as a function of distance to the particle.

Although, as we have just mentioned, the strong nuclear and electrostatic charges cancel each other, virtual particles of antimatter remain attached to real elementary particles, exerting their antigravitational influence.

2. Vector Charges.

In previous publications, we proposed that the chromodynamic, electrostatic and gravitational charges can be represented as complex vectors. For example, electrostatic charges are represented as two real unitary vectors which between each other form an angle of 0^0 if they are of the same sign and an angle of 180^0 if they are of opposite signs. Instead of using colors, the chromodynamic charges of a baryon are represented as three unitary and symmetric real vectors in a plane forming with each other an angle of 120^0. The sum of the three vectors is zero just as the sum of the three colors is white. The gravitational charge is represented by the imaginary vector $\boldsymbol{u}e^{i\pi/2} = \boldsymbol{u}i$. The attraction or repulsion between one charge and another is defined by the complex scalar product of the unitary vectors and is given by [4]:

$$\boldsymbol{ui}.\,\boldsymbol{ui} = e^{i(\propto+\beta)}cos\theta \qquad (2.1)$$

Where θ is the angle which the vectors form with each other and $\propto$ and β are the angles which determine the real or imaginary character of the vector, in which the real nature corresponds to the electrostatic and chromodynamic charges and the imaginary nature corresponds to the gravitational charge for $\propto = \beta = \pi/2$.

In the case of two electrostatic charges of the same sign, specifically, $\propto = \beta = 0$ and $\theta = 0^0$, the scalar product is $+1$ and the charges repel each other. In the case of charges of a different sign, $\propto = \beta = 0$ and $\theta = 120^0$, the scalar product is -1 and the charges attract each other. Since these are chromodynamic charges, where $\propto = \beta = 0$ and $\theta = 120^0$, the scalar products of one of the charges with the two remaining ones are added. This results in -1 and the charges attract each other, which is precisely the behavior of quarks in the nucleons. For gravitational charges where $\propto = \beta = \pi/2$ and $\theta = 0^0$, the scalar product is -1, which means that two masses of matter attract each other, and that two masses of antimatter also attract each other. Concerning gravitational charges where $\propto = \beta = \pi/2$ and $\theta = 180^0$, the scalar product is $+1$ and the charges repel each other. This means that a mass of matter and another of antimatter repel each other [5], an important result as we will see.

For some physicists matter and antimatter attract gravitationally and, for others, they repel. To date, there is no experiment that has verified the gravitational behavior between matter and anti-matter. We propose that they repel.

The proximity of two nucleons - protons or neutrons - in an atom produces a slight asymmetry in each nucleon, resulting in a small vector in both nucleons in the opposite direction from each other, represented with the color red. This is the strong residual force that binds the nucleons and which neutralizes the repulsive electrical charge of protons through the neutrons, as illustrated in Figure 3 [6].

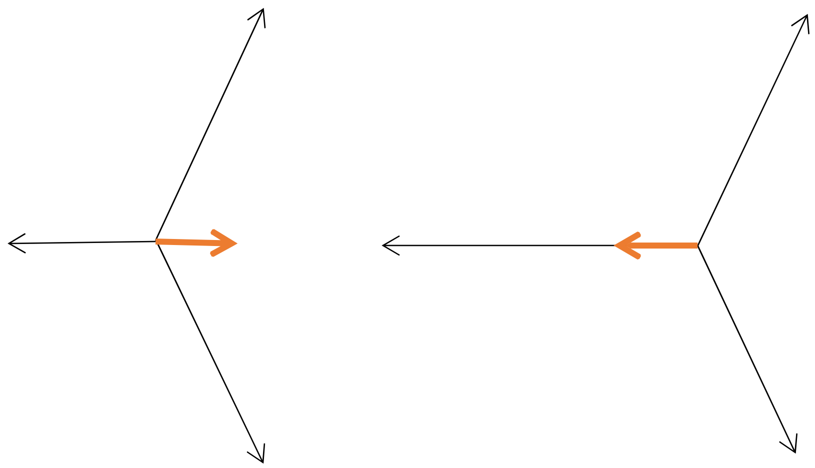

Figure 3. A graphic, vectorial representation of the residual strong force between two nucleons.

The result is a cubic packaging of the nucleons in the atom, which explains the presence of neutrons that allow for the binding of protons, as, for example, is shown in Figure 4 representing the beryllium atom, the more stable isotope with four protons and five neutrons. Here protons are represented by red spheres and neutrons, by blue spheres.

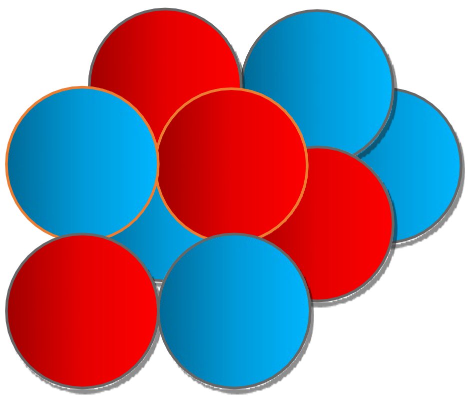

Figure 4. A visual representation of the cubic compaction of nucleons in the berylium atom.

We can represent the unitary charges of the fundamental forces of nature can in a complex vector field of four dimensions, as illustrated in Figure 5. In this way, we can represent the color charges of quarks with the plane formed by the directional vectors ***i, j,*** in which we conventionally define the three charges of a baryon as $\boldsymbol{i}, -\frac{1}{2}\boldsymbol{i} + \frac{\sqrt{3}}{2}\boldsymbol{j}, -\frac{1}{2}\boldsymbol{i} - \frac{\sqrt{3}}{2}\boldsymbol{j}$; the electrostatic charge by $\boldsymbol{k}$ and the gravitational charge by li, where i is the imaginary unit.

Gravity, the only force that has not been unified until today, would possess an imaginary charge just like the gravitational field and the gravitational mass mi. On the other hand, inertial mass m, would be of a real nature, a concept that has not been considered in physics. In this case, the directional vectors form a 90° angle between each other and their cosine defining the scalar product is 0. This means that there is no attraction or repulsion, consistent with the fact that these forces do not interact with each other.

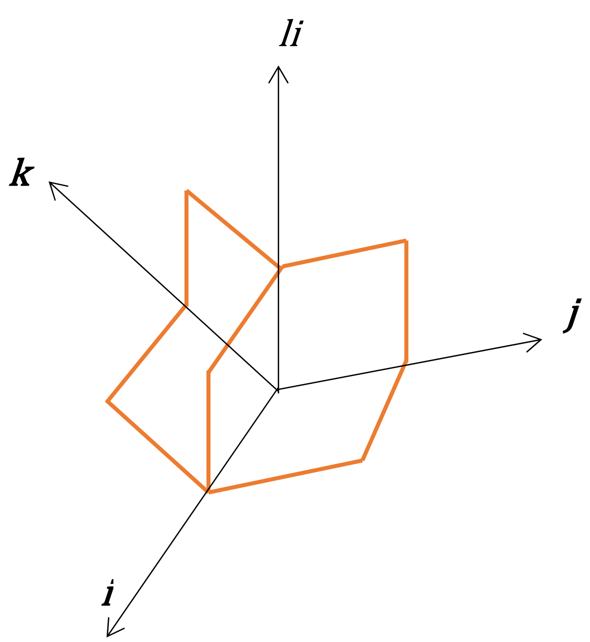

Figure 5. Graphic representation of a complex vectorial field in four dimensions in relation to the chromodynamic, electrostatic and gravitational charges of a particle.

3. Modified Newtonian Gravity.

Similarly to the calculation we did to determine the intensity of the electric charge and energy of the electron in a previous publication [7], we will now proceed with the modified Newtonian gravity.

Let us consider a mass M of spherical and static symmetry. The force of gravitational attraction exerted by the mass on itself in the spherical shell of radius r is represented by:

$$\boldsymbol{F} = -\frac{GM^2}{r^2}\,\boldsymbol{r} \tag{3.1}$$

Since G is the gravitational constant and $\boldsymbol{r}$ is a unit vector oriented towards the center of M, the negative sign shows the direction of the force oriented towards the center of M. The gravitational potential energy E_0 between two points a and b is given by:

$$E_0 = \int_a^b -\frac{GM^2}{r^2}\,.\,dr = -GM^2\left(\frac{1}{a}-\frac{1}{b}\right) \tag{3.2}$$

If we multiply and divide the equation by λ (a length linked to M and for now undetermined) we will obtain:

$$E_0 = -\frac{GM^2}{\lambda}\left(\frac{\lambda}{a}-\frac{\lambda}{b}\right) \tag{3.3}$$

Let's make $\lambda/r = \phi_r$, a function of r, so that:

$$E_0 = -\frac{GM^2}{\lambda}(\phi_a - \phi_b) \quad (3.4)$$

In this way, we obtain the gravitational energy as a function of a new variable ϕ_r . In an analogous way, according to our hypothesis, the energy E_1 generated by the virtual positrons as a function of ϕ_r, whit $n = 1$, would be given by:

$$E_1 = \int_{\phi_a}^{\phi_b} -\frac{GM^2}{\lambda}(\phi_a - \phi_b).\, d\phi = \frac{GM^2}{\lambda}\left(\frac{{\phi_a}^2}{2!} - \frac{{\phi_b}^2}{2!}\right) \quad (3.5)$$

The change of sign is because the gravitational energy of the positrons is positive. Likewise, the gravitational energy of the electrons in the second level of the quantum vacuum, whit $n = 2$, would be given by:

$$E_2 = \int_{\emptyset_a}^{\emptyset_b} \frac{GM^2}{\lambda}\left(\frac{{\phi_a}^2}{2!} - \frac{{\phi_b}^2}{2!}\right) .\, d\phi = -\frac{GM^2}{\lambda}\left(\frac{{\phi_a}^3}{3!} - \frac{{\phi_b}^3}{3!}\right) \quad (3.6)$$

In general, the gravitational energy of a level n of the quantum vacuum would be given by:

$$E_n = \int_{\phi_a}^{\phi_b} (-1)^n \frac{GM^2}{\lambda}\left(\frac{{\emptyset_a}^n}{n!} - \frac{{\emptyset_b}^n}{n!}\right) .\, d\emptyset =$$

$$\frac{GM^2}{\lambda}\left(\frac{{\phi_a}^{n+1}}{(n+1)!} - \frac{{\phi_b}^{n+1}}{(n+1)!}\right) \quad (3.7)$$

The net gravitational potential energy E between a and b would be given by the sum of all gravitational potential energies of the umpteenth level when $n \to \infty$,namely:

$$E = \sum_{n=0}^{n\to\infty} (-1)^{n+1} \frac{GM^2}{\lambda} \left(\frac{\phi_a^{n+1}}{(n+1)!} - \frac{\phi_b^{n+1}}{(n+1)!} \right) \qquad (3.8)$$

Adding and subtracting 1 inside the parenthesis, we obtain:

$$E = -\frac{GM^2}{\lambda} \left(e^{-\frac{\lambda}{b}} - e^{-\frac{\lambda}{a}} \right) \qquad (3.9)$$

Now, this equation gives us the difference of gravitational potential energy between two points located at distances a and b away from the center of M . We can assign a value to a point located at a distance r from the mass, for which is necessary to choose an arbitrary point of reference to which we assign the potential 0. To satisfy this condition, that point must be located at an infinite distance. If we assign point r in a and infinity in b, we will obtain the gravitational potential energy in r:

$$E = -\frac{GM^2}{\lambda} \left(1 - e^{-\frac{\lambda}{r}} \right) \qquad (3.10)$$

Or:

$$E = \frac{GM^2}{\lambda} \left(e^{-\frac{\lambda}{r}} - 1 \right) \qquad (3.11)$$

This energy is always negative. When $r \to 0$, then:

$$E = - \frac{GM^2}{\lambda} \qquad 3.12)$$

which is a finite quantity.

We previously defined λ as a length related to M. We can choose λ so that $M/\lambda = k$ in which k is a constant that defines the connection between M and λ. Consequently, GM/λ will also be a constant equivalent to the square of a speed. Now, the only constant speed in nature is the speed of light so that we can assume that $GM/\lambda = c^2$. Thus, $\lambda = GM/c^2$. By replacing this value in equation 3.12 we have:

$$E = - Mc^2 \qquad (3.13)$$

For the case of the electron that we analyzed in a previous publication [7], when $r \to 0$ the electrostatic energy is represented by $E = m_e c^2$. In an analogous way, the gravitational energy of M when $r \to 0$ would be represented by $E = - Mc^2$. Namely, the gravitational energy of a mass M when $r \to 0$ is its intrinsic energy with a negative sign. Thus, we conclude that the gravitational energy of a black hole with a mass M is a finite magnitude in the modified Newtonian limit and, consequently, in the modified general relativity, unlike the Newtonian and relativistic models which give an infinite value.

This important result excludes an infinite physical magnitude for the gravitational energy something which general relativity leads to. We should mention that the renormalization method in quantum electrodynamics could not be applied to gravity for which – unlike our model - infinite divergence has not been eliminated.

The gravitational energy of a black hole would have a natural limit. This result also leads us to the possibility of establishing an origin for the fundamental forces of nature, including gravity, as differentiated gradients out of the same origin, which is the intrinsic energy $E = Mc^2$.

It is important to mention that gravitational energy in general relativity is based on the intrinsic relativistic energy of mass so that the apparent acceleration derived from it does not contradict the postulate of general relativity which considers gravity as a space-time geometry and not as a force. The gravitational energy is $-\, n\, Mc^2$, where $0 \leq n \leq 1$. When $n = 1$, the maximum negative energy $-\, Mc^2$ is obtained. This energy would be the same in Newtonian mechanics and in general relativity. Its derivative regarding distance gives us the Newtonian gravitational force or the apparent force or acceleration of general relativity. General relativity would be integrated with the other fundamental forces of nature precisely in the intrinsic energy of mass.

Replacing the value $\lambda = GM/c^2$ in equation 3.11 , we will obtain:

$$E = Mc^2 \; (e^{-\frac{GM}{c^2 r}} - 1) \qquad (3.14)$$

an similar wquation to that for the modified energy of the electron with a negative sign:

$$E = m_e \; c^2 \, (1 - e^{-\frac{ke^{-2}}{m_e c^2 r}}) \qquad (3.15)$$

where k is the Coulomb constant.

By expanding the exponential:

$$E = - \; \frac{GM^2}{r} + \frac{G^2 M^4}{2!\, r^2} - \cdots \qquad (3.16)$$

and neglecting the second term onwards (since these are relatively large distances), we will have:

$$E \approx - \frac{GM^2}{r} \tag{3.17}$$

which is the equation of the gravitational potential energy under the Newtonian limit as a particular case.

Dividing equation 3.17 by M, we will obtain the gravitational Newtonian potential V of M in r:

$$V \approx - \frac{GM}{r} \tag{3.18}$$

Dividing equation 3.14 by M, we will obtain the modified gravitational Newtonian potential V of M in r:

$$V = c^2 \left(e^{-\frac{GM}{c^2 r}} - 1\right) \tag{3.19}$$

The graph in Figure 6, for $GM/c^2 = 1$, shows the classic Newtonian gravitational potentials in blue and the modified one in red, as a function of distance to the center of the black hole:

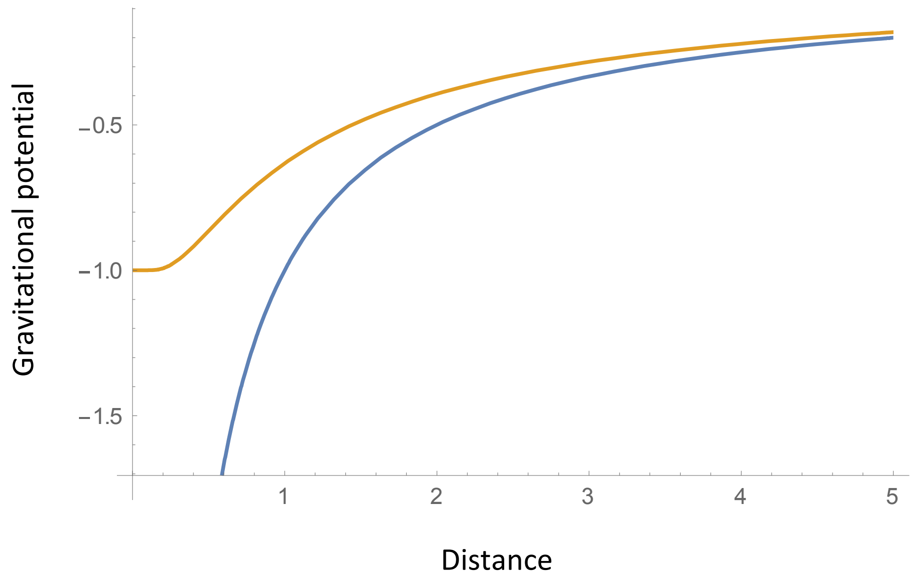

Figure 6. A comparative graph between the classic Newtonian gravitational potential (in blue) and the modified one (in red) as a function of distance from the center of the black hole.

Deriving equations 3.18 and 3.19 concerning r we will obtain the intensity $\boldsymbol{g}$ of the classic and the modified Newtonian gravitational field:

$$\boldsymbol{g} \approx - \frac{GM}{r^2} \boldsymbol{r} \tag{3.20}$$

$$\boldsymbol{g} = - \frac{GM}{r^2} e^{-\frac{GM}{c^2 r}} \boldsymbol{r} \tag{3.21}$$

whose graph is:

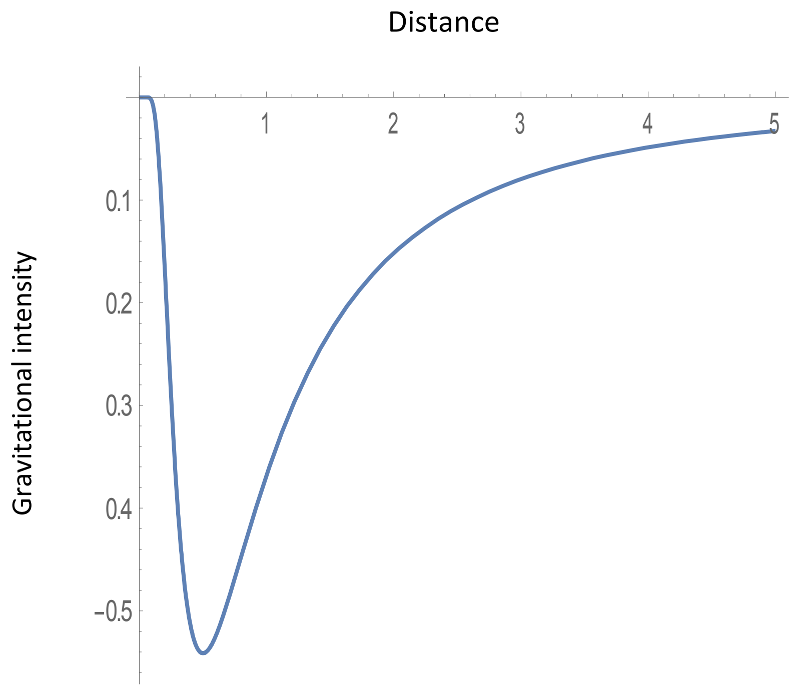

Figure 7. Graphic representation of the intensity of the modified gravitational field.

4. Modified Schwarzschild Metric

Let's consider a static mass M of spherical symmetry. The metric in coordinates (r, t) for a mass without rotation and in the absence of a gravitational field concerning itself in the spherical shell of radius r is the Minkowski metric:

$$ds^2 = c^2dt^2 - dr^2 \qquad (4.1)$$

Deriving in relation to proper time τ we will have:

$$c^2 = c^2t^2 - \dot{r}^2 \qquad (4.2)$$

In the presence of a gravitational field, we will obtain:

$$c^2 = Ac^2\dot{t}^2 - B\dot{r}^2 \tag{4.3}$$

in which A and B are coefficients to be determined and which define the spacetime curvature.

We demonstrate that $Ac^2\dot{t}$ is a constant equal to the relativistic energy per unit of mass, namely, $Ac^2t = E/m$, from which $t^2 = E^2/A^2m^2c^4$.

Replacing this value in equation 4.3 , we obtain:

$$c^2 = \frac{E^2}{AM^2c^2} - B\dot{r} \tag{4.4}$$

Solving:

$$E^2 = AM^2c^4 + ABM^2c^2\dot{r}^2 \tag{4.5}$$

From this equation, we will obtain the gravitational potential energy of M. Subtracting M^2c^4 and dividing by $2Mc^2$ we have:

$$\frac{E^2 - M^2c^4}{2Mc^2} = E_\varphi = \frac{AMc^2}{2} + \frac{ABM\dot{r}^2}{2} - \frac{Mc^2}{2} \tag{4.6}$$

where E_φ is a new energy. Now, we can determine values for A and B so that E_φ represents the gravitational potential energy of M regarding itself, namely:

$$E_\varphi = \frac{AMc^2}{2} + \frac{ABM\dot{r}^2}{2} - \frac{Mc^2}{2} \approx -\frac{GM^2}{r} + \frac{M\dot{r}^2}{2} \tag{4.7}$$

as per equation 4.6 plus the kinetic energy of M.

In order to satisfy the previous equation, $ABM\dot{r}^2/2$ must be equal to the kinetic energy of M, that is, $ABM\dot{r}^2/2 = M\dot{r}^2/2$. Thus, $AB = 1$, from which $B = 1/A$. Since M is a static rest mass without rotation, $\dot{r} = 0$ and $M\dot{r}^2/2 = 0$, then:

$$E_\varphi = \frac{AMc^2}{2} - \frac{Mc^2}{2} \approx -\frac{GM^2}{r} \qquad (4.8)$$

from which:

$$A \approx 1 - \frac{2GM}{c^2 r} \qquad (4.9)$$

Replacing this value in equation 4.9 , we will obtain the Schwarzschild metric for a static mass of spherical symmetry in coordinates (t, r):

$$c^2 = \left(1 - \frac{2GM}{c^2 r}\right) c^2 \dot{t}^2 - \left(1 - \frac{2GM}{c^2 r}\right)^{-1} \dot{r}^2 \qquad (4.10)$$

Schwarzschild obtained coefficients A and B using another method based on the tensor analysis for a Ricci tensor $R_{uv} = 0$ and based on the Newtonian potential $-GM/r$ as an exact solution to Einstein's field equations.

If we substitute $-GM^2/r$ by equation 3.14 , we will obtain:

$$E_\varphi = \frac{AMc^2}{2} - \frac{Mc^2}{2} = Mc^2\left(e^{-\frac{GM}{c^2 r}} - 1\right) \qquad (4.11)$$

from which:

$$A = 2e^{-\frac{GM}{c^2r}} - 1 \quad (4.12)$$

Replacing this value in equation 4.3 , we will obtain the modified Schwarzschild metric:

$$c^2 = \left(2e^{-\frac{GM}{c^2r}} - 1\right) c^2t^2 - \left(2e^{-\frac{GM}{c^2r}} - 1\right)^{-1} \dot{r}^2 \quad (4.13)$$

If in the Schwarzschild metric we substitute the Newtonian potential with the modified Newtonian potential of equation 3.19 , we will obtain the same result. Regarding metrics for rotating and electrically charged black holes, as well as all metrics based on the Newtonian potential, we must replace said potential with the modified Newtonian potential.

5. Geodesics.

The line element is given by:

$$ds^2 = -Ac^2t^2 + B\dot{r}^2 + r^2d\theta^2 + r^2sin^2\theta d\phi^2 \quad (5.1)$$

$$(x^0, x^1, x^2, x^3) = (ct, r, \theta, \phi)$$

where A and B are the coefficients of Schwarzchild's modified metric. Let's define A' y B' as the derivatives of A y B respectively in relation to r . Their values are:

$$A' = \frac{2GM}{c^2r^2}e^{-\frac{GM}{c^2r}} \quad (5.2)$$

$$B' = -\frac{2GM}{c^2r^2}\left(2e^{-\frac{GM}{c^2r}} - 1\right)^{-2} e^{-\frac{GM}{c^2r}} \qquad (5.3)$$

The metric tensor is:

$$g_{uv} = \begin{bmatrix} -A & 0 & 0 & 0 \\ 0 & B & 0 & 0 \\ 0 & 0 & r^2 & 0 \\ 0 & 0 & 0 & r^2 sin^2\theta \end{bmatrix}$$

The Christoffel symbols are:

$$\Gamma^0_{pq} = \begin{bmatrix} 0 & \frac{A'}{2A} & 0 & 0 \\ \frac{A'}{2A} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \qquad \Gamma^1_{pq} = \begin{bmatrix} \frac{A'}{2B} & 0 & 0 & 0 \\ 0 & \frac{B'}{2B} & 0 & 0 \\ 0 & 0 & \frac{-r}{B} & 0 \\ 0 & 0 & 0 & \frac{-r\, sin^2\theta}{B} \end{bmatrix}$$

$$\Gamma^2_{pq} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{r} & 0 \\ 0 & \frac{1}{r} & 0 & 0 \\ 0 & 0 & 0 & -sin\theta cos\theta \end{bmatrix} \qquad \Gamma^3_{pq} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{r} \\ 0 & 0 & 0 & cot\theta \\ 0 & \frac{1}{r} & cot\theta & 0 \end{bmatrix}$$

The equation to find the geodesics is:

$$\ddot{x}^r + \Gamma^r_{pq}\, \dot{x}^p \dot{x}^q = 0 \qquad (5.4)$$

In the current case:

$$\ddot{t} + \frac{A'}{A} t\dot{r} = 0 \qquad (5.5)$$

$$\ddot{r} + \frac{A'}{2B} t^2 + \frac{B'}{2B} + \dot{r}^2 - \frac{r}{B}(\dot{\phi}^2 + sin^2\theta)\dot{\phi}^2 \qquad (5.6)$$

$$\theta + \frac{2}{r}\dot{r}\theta - sin\theta cos\theta\, \dot{\phi}^2 = 0 \qquad (5.7)$$

$$\phi + \frac{2}{r}\dot{r}\phi + 2cot\theta\, \phi\theta = 0 \qquad (5.8)$$

6. Equations of movement and precession of planetary orbits.

The Minkowski metric with spherical symmetry in coordinates (t, r, θ, ϕ) and in the absence of a field is:

$$ds^2 = c^2dt^2 - dr^2 - r^2d\theta^2 - r^2sin\theta d\phi^2 \qquad (6.1)$$

In the presence of a field and, assuming that the metric does not depend on time, while also adopting the standard gauge (in which the metric is not affected under the terms of the solid angle differential), we will have the modified Schwarzschild metric:

$$ds^2 = (2e^{-\frac{GM}{c^2r}} - 1)\, c^2dt^2 - (2e^{-\frac{GM}{c^2r}} - 1)^{-1}\, dr^2 - r^2d\theta^2 -$$

$$r^2 sin\theta d\phi^2 \qquad (6.2)$$

The Lagrangian $\mathcal{L}$ of this equation is:

$$\mathcal{L} = c = \left[(2e^{-\frac{GM}{c^2r}} - 1)\ c^2 t^2 - (2e^{-\frac{GM}{c^2r}} - 1)^{-1} \dot{r}^2 - r^2\theta^2 - r^2 sin\theta \dot{\phi}^2\right]^{\frac{1}{2}} \qquad (6.3)$$

In the equation of motion for t, for a mass m revolving around a mass *M*, as $\partial\mathcal{L}/\partial t = 0$, then we obtain that $d(\partial\mathcal{L}/\partial\, t)/d\tau = 0$. Specifically, $\partial\mathcal{L}/\partial t = cte$. That constant is the relativistic energy per unit of mass *m*:

$$(2e^{-\frac{GM}{c^2r}} - 1)\ c^2\ \ t = \frac{E}{m} \qquad (6.4)$$

When $r \to \infty$, we must have that $(2e^{-\frac{GM}{c^2r}} - 1) \to 1$, so that in the Minkowski metric we find $E = m\gamma c^2$, where $t = r = 1/\sqrt{1 - v^2/c^2}$, in which v is the velocity of *m* with respect to an observer.

In the equation of motion for ϕ, since $\partial\mathcal{L}/\partial\phi = 0$ then we have that $d(\partial\mathcal{L}/\partial\, \dot{\phi})/d\tau = 0$. Namely, $\partial\mathcal{L}/\partial\dot{\phi} = cte$. That constant is the relativistic angular momentum l per unit of mass:

$$r^2 sin^2\theta\ \dot{\phi} = \frac{l}{m} \qquad (6.5)$$

We can demonstrate that the movement between two bodies is found on a plane. For $\theta = \pi/2$, in equation 6.3, we have:

$$c^2 = (2e^{-\frac{GM}{c^2r}} - 1)\, c^2 t^2 - (2e^{-\frac{GM}{c^2r}} - 1)^{-1} \dot{r}^2 - r^2\dot{\phi}^2 \qquad (6.6)$$

Replacing equations 6.4 and 6.5 in equation 6.6 , we will have:

$$c^2 = (2e^{-\frac{GM}{c^2r}} - 1)^{-1} \frac{E^2}{m^2c^2} - (2e^{-\frac{GM}{c^2r}} - 1)^{-1} \dot{r}^2 - \frac{l^2}{m^2r^2} \qquad (6.7)$$

Clearing E^2, subtracting m^2c^4 and dividing by $2mc^2$ we will have a new energy E_φ which is the gravitational potential energy of m with regard to M in r:

$$E_\varphi = mc^2 e^{-\frac{GM}{c^2r}} - mc^2 + \frac{m\dot{r}^2}{2} + \frac{l^2}{mr^2} e^{-\frac{GM}{c^2r}} - \frac{l^2}{2mr^2} \qquad (6.8)$$

Deriving with respect to τ , we have:

$$0 = \frac{GMm}{r^2} e^{-\frac{GM}{c^2r}} \dot{r} + m\dot{r}\ddot{r} + \frac{GMl^2}{mc^2r^4} e^{-\frac{GM}{c^2r}} \dot{r} - \frac{2l^2}{mr^3}\dot{r} + \frac{l^2}{m^2r^3}\dot{r} \qquad (6.9)$$

Clearing $\ddot{r}$:

$$\ddot{r} = -\frac{GM}{r^2} e^{-\frac{GM}{c^2r}} - \frac{GMl^2}{m^2c^2r^4} e^{-\frac{GM}{c^2r}} + \frac{2l^2}{m^2r^3} e^{-\frac{GM}{c^2r}} - \frac{l^2}{m^2r^3} \qquad (6.10)$$

Likewise, the expression for radial acceleration a_r is given by $a_r = \ddot{r} - r\theta^2 - rsin^2\theta\phi^2$. If we consider $\theta = \pi/2$, we will have:

$$a_r = \ddot{r} - r\phi^2 \qquad (6.11)$$

Considering that $l = mr^2\phi$ and equation 6.11, we have:

$$a_r = -\frac{GM}{r^2}e^{-\frac{GM}{c^2r}} - \frac{GMl^2}{m^2c^2r^4}e^{-\frac{GM}{c^2r}} + \frac{2l^2}{m^2m^3}e^{-\frac{GM}{c^2r}} - \frac{2l^2}{m^2r^3}$$

$$(6.12)$$

This is the exact equation for the radial acceleration of m with respect to M. Expanding the exponential in the equation we have:

$$a_r = -\frac{GM}{r^2} + \frac{G^2M^2}{c^2r^3} - \cdots - \frac{GMl^2}{m^2c^2r^4} + \frac{G^2M^2l^2}{m^2c^2r^5} - \cdots + \frac{2l^2}{m^2r^3} - \frac{2GMl^2}{m^2c^2r^4} + \frac{G^2M^2l^2}{m^2c^4r^5} - \cdots - \frac{2l^2}{m^2r^3} \qquad (5.13)$$

Neglecting in the series the terms for relatively large distances we have:

$$a_r \approx -\frac{GM}{r^2}(1 + \frac{3l^2}{m^2c^2r^2}) + \frac{G^2M^2}{c^2r^3}(1 + \frac{2l^2}{m^2c^2r^2}) \qquad (6.14)$$

The first addend of the equation corresponds to the equation of motion in the Schwarzschild metric with a relativistic modification that satisfactorily explains the precession of the perihelion of Mercury of 43 seconds of arc per century. It approaches the relativistic limit.

The second addend corresponds to the modification introduced by us, approximately equivalent to a displacement in the opposite direction of the perihelion by the order of 10^{-8} seconds of arc per century, a magnitude which is difficult to detect, taking into account that the quantum effect of the virtual particles of antimatter manifests in a significant manner at very short distances.

Perhaps these displacements will be detected in the future along with the discovery of new exoplanets or massive bodies rotating around very massive stars.

Expanding the exponential in the equation for the Schwarzschild modified metric while neglecting the terms of the series from the third term on (since these involve relatively large distances), we will obtain - as a particular case - the Schwarzschild metric in accordance with the relativistic limit. When $r \to \infty$, we will obtain the Minkowski metric, coinciding with the Schwarzschild metric and the modified metric at a distance located in infinity free from a gravitational field. When $r \to 0$, we obtain once again a Minkowski metric, coinciding with the absence of a gravitational field in the center of the black hole, with the signs changed. The graph in Figure 8 shows coefficients A in blue and B in red as per the Schwarzschild metric which has been modified with respect to distance r for $GM/c^2 = 1$.

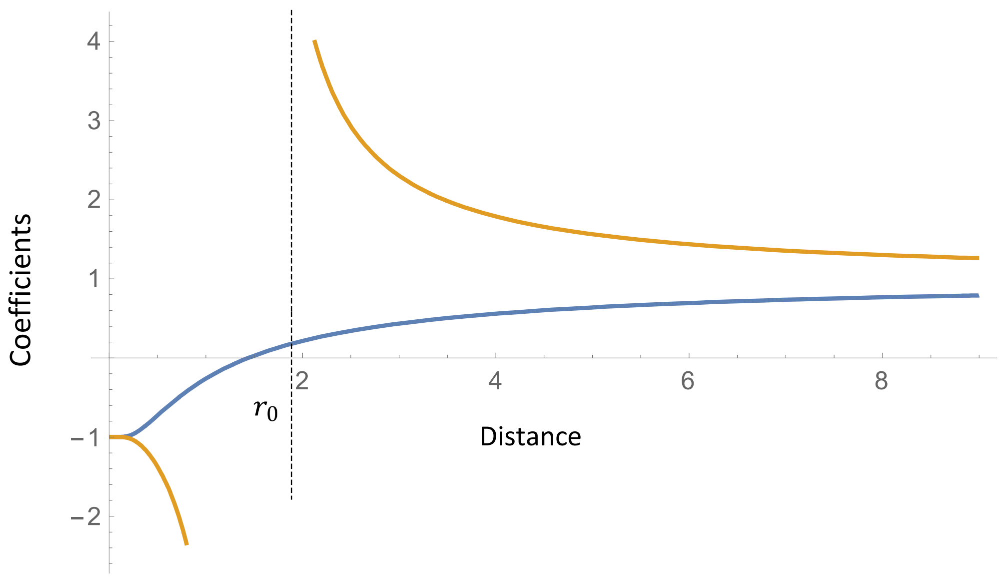

Figure 8. Graphic representation of coefficients A and B in the modified Schwarzschild metric.

When $A = 0$, we will obtain a new radius r_φ for the event horizon, whose value is given by:

$$r_\varphi = \frac{GM}{c^2 ln[2]} \qquad (6.15)$$

This is a smaller magnitude than the Schwarzschild radius for the event horizon given by $r_s = 2GM/c^2$. The graph shows a central symmetry in different scales for coefficients A and B, a mathematical elegance which does not appear in the Schwarzschild metric [8]. To each point r_1 included between 0 and r_φ, corresponds to another point r_2 between r_φ and the infinite, so that coefficients A and B of the first point are the same coefficients as those of the second one but with the opposite sign.

From coefficients A and B, it follows that:

$$r_2 = -\frac{GM}{c^2 r_1 ln[1 - e^{-\frac{GM}{c^2 r_1}}]}, 0 \le r_1 \le \frac{GM}{c^2 ln[2]} \qquad (6.16)$$

whose graph for $GM/c^2 = 1$ is represented by figure 9:

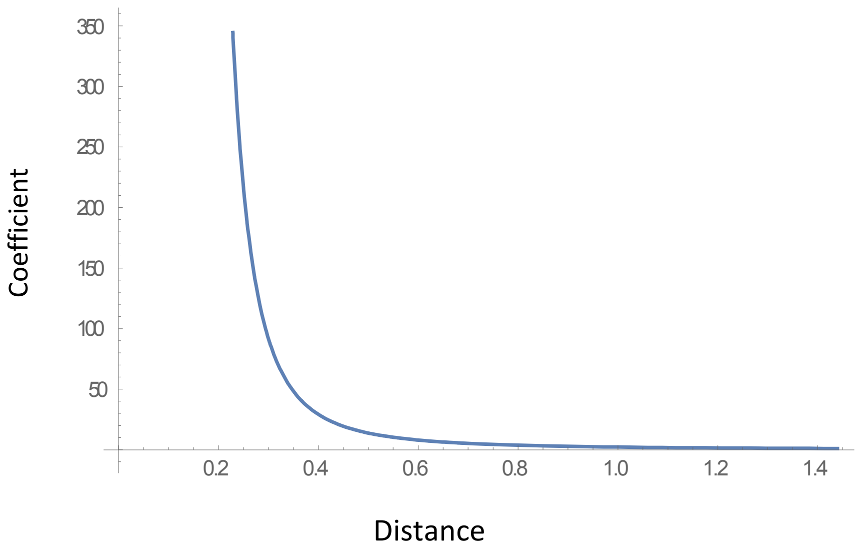

Figure 9. Graphic representation of coefficients A Y B between the center of the black hole and the event horizon.

7. Antimatter black holes.

This central symmetry clearly shows a CPT symmetry (charge, parity and time) in which space and time are distorted and inverted creating a system of coordinates corresponding to an antimatter object as seen by an observer beyond the event horizon. This leads to the conclusion that black holes are formed by antimatter and, consequently, since $-Mi$ is an imaginary gravitational charge as previously mentioned, it will generate a gravitational repulsion against all matter located at a distance greater than the radius $r_\varphi$which determines the event horizon.

The conclusion that black holes are of antimatter and that they, consequently, repel matter which is beyond the event horizon completely changes all of what has been investigated about black holes to date. The mass M that gave rise to the black hole maintains the gravitational attraction on itself during the gravitational collapse because it only repels masses separated from it by a distance greater than r_φ and attracts masses that are located at distances smaller than r_φ, since two masses of antimatter attract each other. Conversely, from the perspective of an observer located in the mass M , no change in the mass occurs, unlike the masses located on a radius greater than r_φ, which for this observer would be transformed into antimatter. The intensity of the gravitational field for $r \geq r_\varphi$ and $\mathrm{GM}/c^2 = 1$ is the inverted graph of figure 7.

As a consequence of the principle of CPT symmetry studied in greater detail in another publication [9], the time of the antimatter virtual particles passes from the past to the future, but in the opposite direction from that of matter, so that these virtual particles neutralize the relativistic time delay in the Schwarzschild metric. This new result substantially differs from general relativity which is based on the Newtonian potential and not on the potential modified by the virtual antimatter particles. With the new metric, we eliminate the infinities of the space-time singularity based on relativity when $r \to 0$. Light rays and any electromagnetic signal are trapped within the event horizon.

As a massive star collapses, its time, as seen by an external observer, slows down until it stops at the event horizon. From then on, time moves backward slowly until it normally passes towards the past where the variation of proper time coincides with that of the observer at the center of the black hole, a process in which entropy is reversed. The graph in figure 10 shows the light cones of this process.

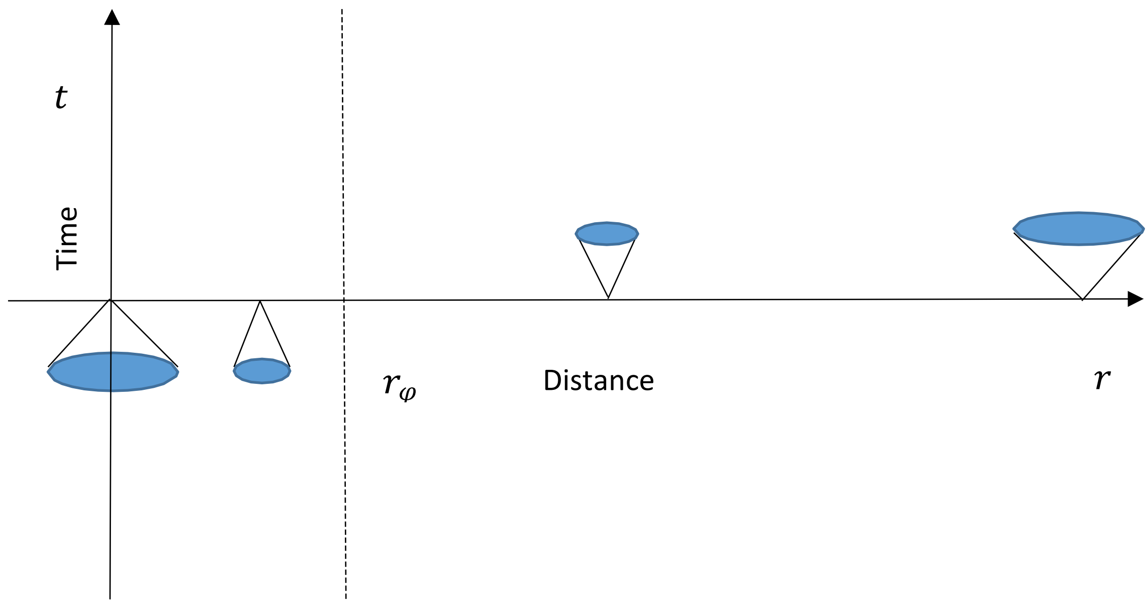

Figure 10. Graphic representation of the light cones as a function of the distance to the center of the black hole.

The same occurs for an observer located inside the event horizon for whom time normally passes towards the future. For an observer located at the center of the black hole, time slows down as he moves away from that center until it comes to a standstill at the event horizon. Henceforth, time begins to pass slowly towards the past as he moves away from that horizon. This occurs until time normally passes towards the past when the variation of proper time coincides with that of the observer at an infinite distance from the center of the black hole, in a region free from gravitational influences. This would be in a Minkowskian space like the one that exists at the center of the black hole. Such a process is represented by the inverted cones in figure 10. Also, entropy is reversed for objects located beyond the event horizon.

While no external or internal observer can see what happens beyond the event horizon, mathematics allows us to deduce the behavior of these events. However, the anti-gravitational effect of black holes is something that can be observed and experimentally verified.

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