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Electromagnetic Radiation from the Antimatter Universe: A Kerr Metric Approach

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Abstract

An antimatter universe that serves in solving the problem of matter-antimatter asymmetry and might shed light on the nature of dark energy was proposed in a previous publication. The present article is an extension of our previous study, where we consider the emitted electromagnetic radiation from the spherical anti-universe as a synchrotron type of radiation that resulted from the centripetal accelerations of the charges on its surface. The radiation power from the relativistic rotating charges is maximized at the equatorial plane and computed together with the direction of the emitted beams of radiation and their angular spread. The base line for the power calculations is done using the classical relativistic Larmor formula in flat spacetime. The general relativity corrections to the classical one due to the large curvature around the compact spherical anti-universe in its local spacetime are calculated. The evaluated general relativistic refinements of the results are done by introducing the axisymmetric exact solution of Einstein's field equation, specifically: The Kerr metric, which is suited to describe space time around celestial rotating objects. The refined calculations took into account the extreme rotation of the anti-universe, which flattens the spherical shape of spacetime around its surface into an oblate shape, causing frame dragging and other relativistic effects. The radiation was mainly dominated by the electromagnetic beams emitted from the free positron charges along the equatorial plane of the anti-universe. The stability of the anti-universe as a compact celestial object under a strong gravitational force and a possible outward internal pressure was discussed, with the study also suggesting that the anti-universe might be consistent with a Kerr black hole. This article is an attempt to explore the spacetime around the antimatter universe and to investigate the effect of the emitted electromagnetic radiation, which permeates and influences our universe. Furthermore, it can be considered as one of the alternative explanations for the observed phenomenon of the cosmic microwave background (CMB) radiation that fills our universe and supports the BIG Bang theory. Moreover, the present research may contribute to the ongoing discussions on the origin of dark energy and put a new perspective on the Hubble tension problem, thus paving the way to an understanding of the forces driving the fast expansion of our universe.

Keywords

Cosmology, Antimatter, Dark Energy, High Energy Astrophysics

1. Introduction

The formation of an antimatter universe, as a consequence of the ejection of primordial *anti-S particles* during the Big Bang that differentiated themselves by counter rotations relative to the ordinary *S particles*, was proposed in a previous publication [1]. During the expansion of spacetime, the anti-universe lagged behind ours in time needed for cooling and formation, in accordance with the relativistic Sagnac's time difference [1]. It took about 380,000 years until the temperature of our universe was sufficiently cooled down for electrons and protons to combine into hydrogen atoms. Then, following the evolution processes which lead to the formation of galaxies, planets and other celestial objects, our universe was formed [2], of which the rotational velocity can be explained as being a remnant of the primordial *S particles*. The subsequent large decrease in rotational velocity due to the cooling and expansion of our universe, might account for the difference in values measured for the Hubble constant and the rate of expansion of our universe, which was actually confirmed in a recent study [3]. On the other hand, following the anti-universe's evolution processes, it took much longer until the formation of the first anti-hydrogen atom (an anti-proton plus a positron around it). Moreover, because the rate of cooling was not fast enough to form the other light anti-atoms, the dense anti-hydrogen gas collapsed under its own gravity and accreted with time, forming a compact object (the anti-universe) [4]. However, due to the high surface temperature, pressure and collisions that led to the ionization of the anti-hydrogen on the surface of the compact object, a thin plasma layer of free heavy anti-protons and light positrons formed, which were slightly separated from each other because of the large centrifugal acceleration. The formation of these free charges on the surface of the compact object (anti-universe) was due to the centrifugal force that pushed the heavy anti-protons apart from the positrons on the outer surface. The centrifugal acceleration of the charged anti-protons and positrons lead, together with the ultra-fast rotation, to the emission of the electromagnetic radiation from the anti-universe, which was dominated by the electromagnetic radiation emitted from the lighter positron layer. As a base line for calculating the radiated power, we used the relativistic Larmor formula employed for the study of radiation from rotating ultra-relativistic charged particles [5] [6]. Moreover, to improve and refine the results by adding general relativistic corrections due to the large curvature of spacetime around the relativistic spinning compact object (the anti-universe), we introduced the Kerr metric, which is the stationary vacuum solution of Einstein Field Equation. Using the Kerr axisymmetric metric with a full covariant form in the calculations is more appropriate since the extreme rotation of the spherically compact object flattens the spacetime into an oblate shape and drags it (frame-dragging [7]). These effects are taken into account by the axisymmetric Boyer-Lindquist coordinates [8] of the Kerr metric. Furthermore, we calculated the direction of the emitted beam of radiation and its angular spread together with the gravitational redshift [2]. However, more detailed and exact calculations of the electromagnetic power emitted from the anti-matter universe require Maxwell's equations in curved spacetime together with the axisymmetric Kerr coordinates, which will be considered in a future work.

2. The Relativistic Larmor's Formula

The non-relativistic Larmor formula for the radiated power from accelerated charges, based on the electric dipole approximation [6], does not apply to charged particles moving with speeds approaching the speed of light $v \sim c$. However, this approximation is reasonable in the limit that the charge is instantaneously at rest having $\boldsymbol{v} = 0$ (since, when the charge is instantaneously at rest it may be still accelerating and hence radiating). We can calculate the radiated power from charges in instantaneous rest frame using the non-relativistic Larmor's formula, and then perform a Lorentz transformation of the power back to the original frame where the charge is moving with any velocity v (since, when the charge is accelerating in the instantaneous rest frame F' at a time t', it will not be the same as in the instantaneous rest frame F at another time t). The power radiated in the inertial frame of reference in which the charge is instantaneously at rest is, $P' = \mathrm{d}E'/\mathrm{d}t'$, where E' is the energy radiated. Further, if we consider the energy-momentum four-vector giving the total energy and momentum of the radiated electromagnetic (EM) fields: $p'_\mu = \left(E'/c, \boldsymbol{p}'\right)$, to obtain the radiated power in the original frame F (when the charge moves with velocity $\boldsymbol{v}$), we should make a Lorentz transformation of energy-momentum four-vector p_μ and then look for the temporal component, we get:

$E/c = \gamma\left(E'/c - \left(\boldsymbol{v} \cdot \boldsymbol{p}'\right)/c\right)$, since $\boldsymbol{p}' = 0$ in the instantaneous rest frame with $\boldsymbol{v}' = 0$.

then $E = \gamma E'$, where $\gamma = \left(1 - \beta^2\right)^{-1/2}$ and $\boldsymbol{\beta} = \boldsymbol{v}/c$. Taking the Lorentz transformation of the differential components of the position of the charge, $\mathrm{d}x'_\mu$, we get for the temporal component, $c\mathrm{d}t = \gamma\left(c\mathrm{d}t' - \left(\boldsymbol{v}/c\right) \cdot \mathrm{d}\boldsymbol{r}\right)$, or $\mathrm{d}t = \gamma \mathrm{d}t'$ (since we are in the instantaneous rest frame where, $\boldsymbol{v}' = \mathrm{d}\boldsymbol{r}'/\mathrm{d}t' = 0$).

The F' is the instantaneous rest frame of the charge and therefore, $\mathrm{d}t'$, is the proper time interval and $\mathrm{d}t = \gamma \mathrm{d}t'$. Therefore, $\mathrm{d}E/\mathrm{d}t = \mathrm{d}E'/\mathrm{d}t'$ and hence, $P = P'$. This shows that the radiated power is a Lorentz invariant scalar. In the F' frame we can use the non-relativistic Larmor formula (in cgs units) [9] [10],

$$P = 2/3\left(q^2 a'^2 / c^3\right), \tag{1}$$

where q is the charge of the particle and a'^2 is the square of its acceleration in the rest frame F'.

In order to get an expression for P in any inertial frame F without referring to the frame F', we should find a Lorentz invariant scalar to replace a'^2. We must find, therefore, the four-acceleration α_μ of the charged particle:

$$\alpha_\mu = \mathrm{d}u_\mu / \mathrm{d}t' = \gamma \mathrm{d}u_\mu / \mathrm{d}t = \gamma \mathrm{d}/\mathrm{d}t\left(\gamma c, \gamma v\right),$$

The temporal part is given by, $\gamma c \mathrm{d}\gamma/\mathrm{d}t$, while the spatial part is, $\boldsymbol{\alpha} = \gamma^2 \mathrm{d}\mathbf{v}/\mathrm{d}t + \gamma \mathbf{v} \mathrm{d}\gamma/\mathrm{d}t$.

We get from the temporal part: $\mathrm{d}\gamma/\mathrm{d}t = 1/c^2\left(\gamma^3 \mathbf{v}\cdot\boldsymbol{a}\right)$, but as $\boldsymbol{v} \to 0$, we get $\gamma = 1$ and hence $\mathrm{d}\gamma/\mathrm{d}t \to 0$, and we also have for $\boldsymbol{v} = 0$: the spatial acceleration $\boldsymbol{a}$, goes to $\mathrm{d}\boldsymbol{v}/\mathrm{d}t = \boldsymbol{a}$, and the temporal acceleration goes to zero. Hence, $\alpha_\mu \to (0, \boldsymbol{a})$ and $\alpha_\mu^2 \to |\boldsymbol{a}|^2$. Thus, we can write in any inertial frame, the power as:

$$P = 2/3\left(q^2 \alpha_\mu^2 / c^3\right). \tag{2}$$

This is the relativistic Larmor formula, and the 4-acceleration of the charged particle is: $\alpha_\mu = \left(c\gamma \mathrm{d}\gamma/\mathrm{d}t, \gamma^2 \mathrm{d}\mathbf{v}/\mathrm{d}t\, t + \gamma \mathbf{v} \mathrm{d}\gamma/\mathrm{d}t\right)$. It is easy to show that, $\alpha_\mu^2 = \gamma^4\left[a^2 + \gamma^2\left(\boldsymbol{v}\cdot\boldsymbol{a}\right)^2/c^2\right]$.

For a charged particle moving in circular motion, $\boldsymbol{v}\cdot\boldsymbol{a} = 0$ (since, '$\boldsymbol{v}$' is the tangential velocity and '$\boldsymbol{a}$' is the radial acceleration ($\boldsymbol{v} \perp \boldsymbol{a}$)) and thus we have, $\alpha_\mu^2 = \gamma^4 a^2$. Substituting in Eq. (2), we get Larmor formula for the radiation power from a relativistic charged particle in a circular orbit.

$$P = 2/3\left(q^2 a^2 / c^3\right)\gamma^4. \tag{3}$$

Hence, we conclude that for a relativistic charged particle motion in a circular orbit the radiated power is increased by a factor of γ^4 compared to the non-relativistic one.

The relativistic Larmor formula for a rotating charged particle is written in SI units as [9,10]:

$$P = \left(\mu_0 q^2 a^2 / 6\pi c\right)\gamma^4, \tag{4}$$

where, μ_0 is the permeability of free space, q is the charge of the particle, a is the acceleration of the particle and c is the speed of light.

Now consider the anti-universe as a relativistic rotating astrophysical compact object having a mass M, a radius R and a total charge Q (uniformly distributed over the surface). Assuming that it is spherically symmetric, rotating about the z-axis with an angular velocity ω (see **Figure 1**). The surface charge implies a charge density, $\sigma = Q/4\pi R^2$, and the charged elements on the surface (positrons) undergo circular motion due to the rotation of the object (the anti-universe).

Each charged element has a spatial polar coordinate (R, θ, ϕ), where at any polar angle θ from the rotation axis, the distance from the axis is ($R\sin\theta$) and its tangential speed is $v = \omega(R\sin\theta)$. The magnitude of the centrifugal acceleration is, $a = v^2/(R\sin\theta) = \omega^2(R\sin\theta)$, and the Lorentz factor γ for the element is, $\gamma = (1 - v^2/c^2)^{-1/2}$. Since we assume that the object is in ultra-relativistic rotation, the tangential speed at the equator ($\theta = \pi/2$), $v = \omega R$, approaches the velocity of light c. Hence, the value of γ at the equator is extremely high. Although a uniformly charged sphere rotating about its axis of symmetry might cause the radiation fields from opposite sides to interfere destructively leading to a zero net radiation, in our case the ultra-high relativistic beams of radiation at the equatorial plane dominate and significantly reduce the cancelation effects similar to a synchrotron radiation [11]). The direction of the radiated energy flux is indicated by the Poynting vector $\boldsymbol{S}$ which represents the directional energy flux or the power flow of an electromagnetic wave [6], which is given by $\boldsymbol{S} = (1/\mu_0)\boldsymbol{E} \times \boldsymbol{B}$, and its direction is tied to the motion of the accelerated charge. Along the circular motion the electric and the magnetic fields change directions according to the rotation direction of the particle, while the Poynting vector keeps with the direction of the particle's velocity, tangential to the circular orbit. For high relativistic velocities the radiation will be strongly beamed in the direction of the charged particles' instantaneous velocity due to relativistic effects. The radiation emitted will be in a tight cone along the particle's velocity vector at each point in its orbit.

In relativistic astrophysics, compact objects rotating at high speeds are approximated by their equatorial dynamics [11]. Thus, we can consider that the total surface charge Q radiates as if it is moving with the equatorial speed $v = \omega R$. Hence, the relativistic radiation power from the anti-universe can be approximately, given by,

$$P \approx \left(\mu_0 Q^2 \omega^4 R^2 / 6\pi c\right)\gamma^4, \tag{5}$$

where, $a = \omega^2 R$. In order to improve and refine the results of the classical relativistic Larmor's formula in flat space time, we should consider general relativity corrections, and to account for the effects of spacetime curvature around the ultra-fast rotating compact object. This was done by introducing the Kerr metric in the calculations. The spacetime around fast rotating massive objects, co-rotates with the object and hence is wrapped by its mass and fast rotation while changing its shape from spherically symmetric to an axisymmetric oblate shape. Hence, it was appropriate to consider the Kerr metric which applies to rotating objects in axially symmetric spacetime.

3. The Kerr Metric Approach

Exact solutions of Einstein field equation in empty space are usually expressed in metrics. Among these solutions is the Kerr solution which is perfectly suited for the study of celestial rotating objects in vacuum, and which is of special importance in astrophysics. It describes the geometry of stationary empty spacetime around axially symmetric rotating objects. The Kerr metric is typically expressed in Boyer-Lindquist coordinate (t, r, θ, ϕ), that is characterized by its axisymmetric properties. The line element of the Kerr metric is given by [12] [13]:

$$\mathrm{d}s^2 = -\left(1-2Mr/\rho^2\right)\mathrm{d}t^2 + \left(\rho^2/\Delta\right)\mathrm{d}r^2 + \rho^2\mathrm{d}\theta^2 - \left(4Mra\sin^2\theta/\rho^2\right)\mathrm{d}t\mathrm{d}\phi + \left[r^2 + a^2 + \left(2Mra^2\sin^2\theta/\rho^2\right)\right]\sin^2\theta\mathrm{d}\phi^2, \quad (6)$$

where, $\rho^2 = r^2 + a^2\cos^2\theta$, $\Delta = r^2 - 2Mr + a^2$, $a = J/M$, M is the mass of the rotating object, r is the distance from the center of the rotating object, and J is the angular momentum of the object. 'a' is called the specific angular momentum or the spin parameter. The metric $g_{\mu\nu}$ in Equation (6), has non-zero diagonal components g_{tt}, g_{rr}, $g_{\theta\theta}$, $g_{\phi\phi}$ and off-diagonal components $g_{t\phi} = g_{\phi t}$, reflecting the frame-dragging effect of fast rotation, while the axisymmetric coordinates imply no dependence on the angle of rotation ϕ. Therefore, the frame-dragging effect arises from the $\mathrm{d}t\mathrm{d}\phi$ cross term, which couples time and azimuthal coordinates. The components of the Kerr metric can be obtained from Equation (6) by substituting:

$g_{tt} = -\left(1-2Mr/\rho^2\right)$, $g_{rr} = \left(\rho^2/\Delta\right)$, $g_{\theta\theta} = \rho^2$,

$g_{\phi\phi} = \left[r^2 + a^2 + \left(2Mra^2\sin^2\theta/\rho^2\right)\right]\sin^2\theta$, $g_{t\phi} = g_{\phi t} = -\left(4Mra\sin^2\theta/\rho^2\right)$.

The presence of the non-zero component $g_{\phi t}$ in the metric, introduces general relativity effects on particles' trajectories [14]. Because of the symmetric rotation about the Kerr rotation (aligned with the z-axis), the metric is independent of ϕ and the trajectory conserves the angular momentum p_ϕ. Thus, the trajectory will have [14] [15]:

$$p^\phi/p^t = \mathrm{d}\phi/\mathrm{d}t = g^{\phi t}/g^{\phi\phi} \equiv \omega_{drag}\left(r,\theta\right), \quad (7)$$

at which the observer's worldline remains orthogonal to the hypersurface of constant time. For such observer, the 4-vector has a form where the spatial components are dragged along with the rotating object. ω_{drag} (r, θ) can be obtained for the Kerr metric by evaluating the contravariant components $g^{\phi t}$ and $g^{\phi\phi}$. This effect is present in any metric for which $g_{\phi t} \neq 0$, *i.e.*, for any rotating celestial object. This important result shows that if a particle having (p_ϕ) dropped from infinity will be dragged by the influence of gravity and acquires an angular velocity, in the same sense as that of the source of the Kerr metric. To compute ω_{drag} we should first find the matrix inverse of the covariant metric to get the contravariant metric $g^{\mu\nu}$, *i.e.*, by solving the matrix equation, $g^{\mu\nu}g_{\nu\lambda} = \delta^\mu{}_\lambda$, (where $\delta^\mu{}_\lambda$ is the Kronecker delta). Thus, we get:

$$g^{\phi t} = -2Mra/\rho^2\Delta, \quad g^{\phi\phi} = -\left[r^2 + a^2 + \left(2Mra^2\sin^2\theta\right)/\rho^2\right]/\Delta\sin^2\theta. \quad (8)$$

Substituting in equation (7), the simplified form of ω_{drag} at the equatorial plane will be given by,

$$\omega_{drag} = -g^{\phi t}/g^{\phi\phi} = 2Mra/\left(r^4 + r^2a^2 + 2Mra^2\right). \quad (9)$$

The emitted radiation is beamed in the equatorial plane tangential to the surface of the object and perpendicular to the radial distance from the axis of rotation (θ = 0), **Figure 1**.

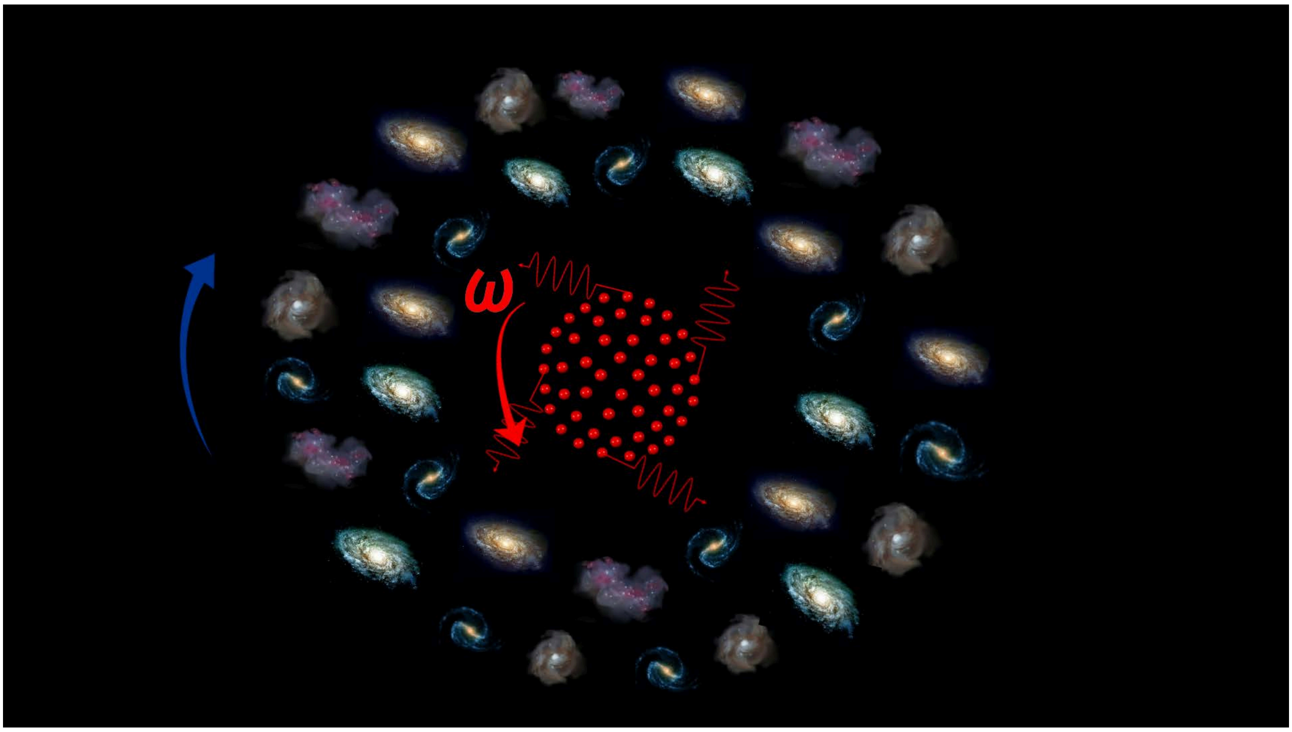

Figure 1. An artistic cross-sectional view illustrating: (a) Our universe in blue, (b) The fast rotating anti-universe in red, emitting the electromagnetic radiation.

The dual universe consists of our universe together with its antimatter counterpart at its core.

The beam is centered on the tangential direction and is spread in a narrow cone of width $\Delta\theta \approx 1/\gamma$. The frame dragging shift [7] [14], is given by ω_{drag}, which is the angular velocity where the spacetime is dragged around the rotating object. This shift is caused by the relativistic rotating object, which affects the emitted electromagnetic waves by decreasing their frequency and hence reducing the energy of the propagated radiation. It is usually observed near the source of radiation, but it is diluted at far distance (where, $M \ll r$, in natural units $G = c = 1$). At very far distances the spacetime is approximately flat, approaching Minkowski spacetime.

The other general relativity effect is the curvature effect due to the heavy mass of the rotating object; this is described by the Riemann tensor $R^{\lambda}{}_{\sigma\mu\nu}$ which is non-zero and significant near the oblate region outside the rotating compact object. This tensor is non-zero in Kerr spacetime, and is given by,

$$R^{\lambda}{}_{\sigma\mu\nu} = \partial_{\mu}\Gamma^{\lambda}{}_{\nu\sigma} - \partial_{\nu}\Gamma^{\lambda}{}_{\mu\sigma} + \Gamma^{\lambda}{}_{\mu\rho}\Gamma^{\rho}{}_{\nu\sigma} - \Gamma^{\lambda}{}_{\nu\rho}\Gamma^{\rho}{}_{\mu\sigma} \tag{10}$$

Computing $R^{\lambda}{}_{\sigma\mu\nu}$, requires the connection coefficients known as "Christoffel symbols", $\Gamma^{\lambda}{}_{\mu\nu}$, given by,

$$\Gamma^{\lambda}{}_{\mu\nu} = \frac{1}{2} g^{\lambda\sigma}\left(\partial_{\mu} g_{\nu\sigma} + \partial_{\nu} g_{\mu\sigma} - \partial_{\sigma} g_{\mu\nu}\right) \tag{11}$$

However, we used known results for Riemann tensor in Boyer-Lindquist coordinates, with the non-zero components listed in the standard book by Chandrasekhar [15]. The relevant component is: $R_{trtr} = g_{rr}R^{r}{}_{trt}$, where at the equatorial plane

g_{rr} is given by, $g_{rr} = r^2/\Delta$. The R_{trtr} component is simplified by the Kerr metric, and is given approximately by,

$$R_{trtr} \approx Mr\left(r^2 - 3a^2\cos^2\theta\right)\Big/\left(\rho^2\right)^3, \quad (12)$$

where, its value near the equatorial plane goes to, $R_{trtr} \sim M/r^3$, (adjusted for Kerr terms). The Riemann tensor is relevant to describe the curvature effects which cause tidal stretching in the radial direction, and which grow as r decreases towards the surface of the object.

Thus, the strong curvature near the massive object is captured by the Riemann tensor which is significantly large near the surface. However, the trace of the Riemann tensor, called the Ricci tensor, is obtained by cancelation and contraction of indices, $R_{\mu\nu} = R^{\lambda}{}_{\mu\lambda\nu}$, where in vacuum it goes down reaching zero. Thus, even at the strong curvature region outside the rotating compact object, $R_{\mu\nu} \approx 0$ because of the empty spacetime. The Ricci tensor is giving by [7],

$$R_{\mu\nu} = \partial_\lambda \Gamma^\lambda{}_{\mu\nu} - \partial_\nu \Gamma^\lambda{}_{\mu\lambda} + \Gamma^\lambda{}_{\sigma\lambda}\Gamma^\sigma{}_{\mu\nu} - \Gamma^\lambda{}_{\sigma\nu}\Gamma^\sigma{}_{\mu\lambda}, \quad (13)$$

The non-zero components, R_{tt}, R_{rr}, and the Riemann Tensor R_{trtr} describing curvature, affect the electromagnetic field.

Finally, the Kerr metric induces curvature and frame-dragging effects as a consequence of the central massive axisymmetric rotating compact object (the anti-universe). The curvature, oblateness and frame-dragging at the equatorial plane $\theta = \pi/2$, are maximized.

Further, we tried to repeat the calculations using the Kerr-Newman metric [16] which describes the spacetime geometry around a rotating massive object that is electrically charged. It is an exact vacuum solution to Einstein field equation and is considered a generalization to Kerr metric solution. The difference in the results between the two metrics was minimal. The Kerr-Newman metric is not often used in astrophysics, since observed astronomical objects do not possess an appreciable net electric charge. Therefore, the Kerr-Newman metric is primarily of theoretical interest.

4. A Numerical Example and Discussions

In this section, I will assign some specific numbers for the Kerr parameters related to the compact massive object and subsequently I will calculate the power of the electromagnetic radiation, the general relativity covariant refinement and corrections.

The parameters are (in SI units):

- mass $M = 100M_\odot$ Solar mass ≈ 1.989×10^{32} Kg, in natural units ($G = c = 1$): $M = GM_{SI}/c^2 \approx 1.477 \times 10^5$ m.
- radius $R = 150$ Km = 1.5×10^5 m.
- the surface density of the positron's $n \approx 2 \times 10^{17}/\text{m}^2$.
- tangential velocity $v = 0.99c \approx 2.968 \times 10^8$ m/s.
- angular velocity $\omega = v/R \approx 1.978 \times 10^3$ rad/s.

- centrifugal acceleration $a = v^2/R \approx 5.873 \times 10^{11}$ m/s^2.
- angular momentum $J = I\omega = (2/5MR^2)\omega = 3.54 \times 10^{45}$ Kg·m^2/s.
- spin parameter $a = J/M = 1.78 \times 10^{13}$ m^2/s.
- Lorentz's factor $\gamma = (1 - v^2/c^2)^{-1/2} \approx 7.07$, ($\gamma^4 \approx 2500$).
- Permeability of empty space $\mu_0 = 4\pi \times 10^{-7} = 1.256 \times 10^{-6}$ H/m.
- Gravitational constant $G = 6.674 \times 10^{-11}$ m^3·Kg^{-1}·s^{-2}.

4.1. The Power of the Electromagnetic Radiation

The centrifugal acceleration of the object's charged particles generates time varying electric and magnetic fields which radiate electromagnetic waves. Assume a spherical object with radius R, hence the surface area $A \approx 2.8 \times 10^{11}$ m^2, thus, the total charge of positrons on the surface will be $Q = n \times A \times e^{+} \approx 9\times10^9$ Coulomb. In relativistic astrophysics, the majority of the charged particles on the surface of the ultra-fast rotating compact object are considered to be moving on the equatorial plane with the speed, $v = \omega R$, carrying the total surface charge Q and emitting a considerable amount of radiation [11]. Therefore, the radiative power emitted from the positrons on the surface of the anti-universe can then be calculated approximately by the classical-Larmor relativistic formula Equation (5), given by:

$$P_{clas.} \approx 1.56 \times 10^{31} \text{ W}.$$

It is the non-relativistic power value of Larmor's formula Equation (2), boosted by the γ^4 factor due to the charged particles' relativistic speed. The power radiated exceeds the solar luminosity (3.8×10^{26} W) by about 5 orders of magnitude, plausible for a compact object.

4.2. The General Relativity Refinement and Corrections

- **Frame dragging shift**

The emitted radiation is beamed in the equatorial plane at $\theta = \pi/2$, with a narrow cone of a width given by, $\Delta\theta \approx 1/\gamma \approx 0.14$ rad. $\approx 8^{\circ}$. To compute the beam dragging shift when observed by a zero angular momentum observer and assuming a near-extremal case of stability at $a \approx M$ (in natural units), we get by substituting in equation (9): $\omega_{drag} \approx 0.33 \times 10^{-5}$ m^{-1}, and in SI units $\omega_{drag} \approx (0.33 \times 10^{-5})c \approx 10^3$ rad./s near the surface of the object which decreases at large distances from the object.

- **Gravitational redshift**

The Kerr metric which describes the spacetime around a rotating mass, the redshift factor z, for a photon emitted from a distance $r = R$ (assuming emission from the equatorial plane) and observed at infinity, is given by:
$1 + z = \nu_{\text{emitted}}/\nu_{\text{observed}} = \sqrt{g_{tt,\infty}/g_{tt}}$, at infinity $g_{tt,\infty} = -1$, and $g_{tt} = -\left(1 - 2GM/c^2 R\right)$ is its time dilation component (in SI units). Redshift, therefore, approximately is given by $z \approx \left(1/\sqrt{-g_{tt}}\right) - 1 \approx 0.02$. Thus, the radiation power is corrected and given by,
$P_{GR} \approx P_{clas} \cdot (1+z)^2 \approx 1.56\times10^{31} \cdot (1.02)^2 \approx 1.62\times10^{31}$ W, which reaches the observer, with a slight modification because of curvature and frame-dragging. The

power is slightly, increased because of frame-dragging.

The covariant curvature near the surface is given by $R_{trtr} \approx 0.59 \times 10^{17}$ m^{-2}, while at far distance (e.g., 10^{15} m) it is about 1.99×10^{-13} m^{-2}, showing strong curvature at the surface which is weakened at large distances giving a minimal impact when the spacetime is nearly flat.

Full and more refined treatment for the radiative power emitted, requires solving Maxwell's equations in the curved antisymmetric Kerr spacetime.

5. Stability of the Anti-Universe

The substantial amount of electromagnetic radiation power emitted from the anti-universe supports its behaviour as an ultra-relativistic rotating compact object [4]. The high pressure at its surface, due to the gravitational compression and rotation, leads to the ionization of the anti-hydrogen and the formation of a plasma layer from anti-protons and positrons.

The gravitational force between the compact object and anti-protons on the surface, is given by $F = GMm_p/R^2 \approx 9.77 \times 10^{-16}$ N, thus the acceleration of the anti-protons = $F/m_p \approx 5.82 \times 10^{11}$ m/s^2, ($m_p \approx 1.67 \times 10^{-27}$ Kg). This high acceleration participates through collisions in ionizing the anti-hydrogen atoms on the surface. Also, the relativistic surface speed ($v = 0.99c$), causes frequent collisions and further ionization.

The stability of the anti-universe should be satisfied by the following two conditions [14]:

1) Rotational stability:

The rotational stability condition is fulfilled if the surface velocity $v \le v_{\text{Kepler}}$, where $v_{\text{Kepler}} \approx \sqrt{GM/R} \approx 2.98\times10^8$ m/s . This velocity matches the equatorial velocity $v \approx 2.968$ x 10^8 m/s.

2) Structural stability:

The structural stability condition is fulfilled if there is a balance between the inward gravitational force which is related to the value of the compactness parameter C, and the outward internal pressure. According to the previously assumed parameters, the value of the compactness of the anti-universe is, $C = GM/c^2R \approx$ 0.98. This value indicates an extremely high gravitational force, and hence suggests an intense internal pressure to support the balance and to prevent a gravitational collapse. For typical celestial compact objects, for example a white dwarf or a neutron star [4]: (i) For a white dwarf the stability relies on electron degeneracy pressure supporting $M < 1.4M_0$ with compactness $C \sim 10^{-4}$, (ii) For a neutron star, the stability relies on neutron degeneracy pressure and nuclear forces, supporting $M < 2.5M_0$ with compactness $C \sim 0.1$ - 0.2.

The assumed compact object's mass (anti-universe) of $100M_0$ and its compactness number $C \approx 0.98$, are exceeding the limits of white dwarfs and neutron stars. Hence, the stability of the anti-universe requires an exotic mechanism to produce an outward internal pressure that is much stronger than neutron degeneracy pressure and to prevent gravitational collapse, this might include anti-quark matter or a modified gravity theory [17]. Alternatively, the heavy mass, the extreme compactness and the ultra-fast rotation of the anti-universe are consistent with a Kerr black hole, which is a more likely configuration. In case of black hole regime, the stability mechanism does not require internal pressure since it is defined by its event horizon [14].

6. Conclusions

In this paper, the counter (antimatter) universe is treated as a spherically symmetric rotating anti-hydrogen compact object that emits electromagnetic radiation from its surface charges, which were formed by ionization. The radiation is emitted mainly by the positron layer on the surface because of the large centrifugal acceleration resulting from the ultra-relativistic speed of rotation. The radiation power is calculated using the relativistic Larmor's formula and shows a pronounced energy flux peaking in the equatorial plane at ($\theta = \pi/2$) and diminishing toward the rotation axis at ($\theta = 0$). The radiation is beamed in the tangential direction to the surface of the ultra-relativistic rotation of the compact object (anti-universe) while spreading in a narrow cone similar to synchrotron radiation.

The Kerr metric, which is perfectly suited to describe the empty spacetime around any axisymmetric rotating celestial object, is introduced in order to refine the calculations and to account for general relativity effects. Thus, it was possible to compute the strong curvature near the surface of the compact object that is weakened at far fields, as well as the beam-dragging angular shift, the gravitational redshift, and the modified radiation power.

The electromagnetic radiation (the S-radiation) from the antimatter universe enters and permeates through our universe, possibly participating in its fast expansion. The fact that the rate of expansion of our universe would have started to accelerate about six billion years ago [18] could be related to the large lagging in time between the formation of the antimatter universe and our universe. It is also proposed that this high energy radiation emitted from the anti-universe is cooled with the expansion of the space to lower energies (low frequencies), leading to the cosmic microwave background radiation observed in our universe at the present time [18]. This picture is consistent with the standard cosmological model, which assumes the Big Bang marks the beginning of our universe's evolution. Moreover, the results of the numerical example showed that the anti-universe might be consistent with a Kerr black hole.

The present research may contribute to ongoing discussions on the origin of dark energy, thus paving the way to the understanding of the fast expansion of our universe.

Finally, on the basis of this publication and the previous one [1], it appears that our universe should be considered as having a dual nature, consisting of a "matter constituent" in which we exist, together with an "antimatter constituent" located at its core.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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