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A Model for a Dual Universe

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Abstract

A model for a dual universe is proposed, based on the assumption that simultaneously with our universe an anti-matter counterpart was initiated immediately following the Big Bang. At the heart of the model is a primordial anti-particle that differentiates itself from its counterpart, a previously hypothesized *S-particle* responsible for the formation of our own universe, through its course of rotation. The angular rotation of the anti-particle, in accordance with space-time rotation, together with the counter rotation of the *S-particle*, resulted in a time difference in the formation processes of both universes and consequently led to a large distance between the spatial locations occupied by our universe and its dual counterpart in the same space-time continuum. The existence of this anti-matter universe might solve the present mystery of matter anti-matter asymmetry and thus explain why hardly any free anti-matter can be observed in our universe. Moreover, the model implicates the possibility of the presence of a repulsive gravitational force exerted by the clusters of anti-particles in the anti-matter universe upon our universe. The repulsive gravitational force from the clusters of antiparticles in the dual universe as a whole upon our universe is completely different from the electrostatic repulsive force between similarly charged particles. It is also different from that due to possible gravitational or anti-gravitational interaction between individual matter and antimatter or particle and its antiparticle that might violate the CPT invariance, the theory of general relativity or the law of energy conservation. It is rather, a kind of negative gravity that affects our universe as a whole, due to the opposite course of rotation of the dual anti-universe relative to ours. The effect of this opposite rotation of the dual universe can cause anti-gravitational waves that penetrate our universe interacting with the space-time mesh around the galaxies in our universe as a whole, resulting in a negative-like curvature in the shape of the space around them. This negative curvature pushes the galaxies outward, away from each other, leading to the accelerated expansion of our universe. The continuous anti-gravitational waves that permeate and fill our universe might cause a constant background ripples (space fluctuations) in the space of our solar system that can be experimentally observed. The repulsive force exerted by our dual universe could together with the expansion of space-time, influence our universe and might yield more insight on the origin of dark energy.

Keywords

Cosmology, Antimatter, High Energy Astrophysics, Particle Physics

1. Introduction

In a previous publication [1], a cosmological model for the very early universe was proposed. The model was based on a hypothesized primordial particle, the so-called "*S-particle*", that following the Big Bang was violently ejected with both linear and angular velocities and extremely high-frequency radiation into all spatial directions. The amount of mass-energy density was tremendously high at the beginning of the explosion. The structure of the space-time mesh was created simultaneously with the Big Bang (the point of singularity) while the ejection of the *S-particles* and radiation were spherically symmetric. It was proposed that in the periods that followed, during the expansion and cooling of the universe, the *S-particles* were subjected to two geometrical phase transitions that gave them their mass and altered their dynamics of motion, hence leading to the formation of the known fundamental particles including dark matter [1] [2]. In this article it is shown that the *S-particle* model in addition to providing an explanation for the formation of our universe [1], implies the existence of a parallel anti-particle universe as well. This anti-universe is formed as a result of the course of opposite-rotating part of the primordial *S-particles*, in accordance to the laws of symmetry in physics. It is shown that the *S-particles* counter-rotating with respect to the direction of rotation of space-time continuum, are propagating at a faster rate than their anti-particles that are co-rotating with the rotation of space-time. Therefore, consequently the dual (anti-matter) universe is lagging in location with respect to our universe. The dual or anti-matter universe may be considered as a negative universe, which through its opposite direction of rotation with respect to ours, is likely to exert a repulsive anti-gravity force on our universe.

This anti-gravitational force together with the expansion of space time, might be the source of dark energy that influences our universe.

In the next sections we will examine the geodesics and the space-time world-lines of the *S-particles*.

2. The Physical Space-Time System of Reference and *S-Particle* Geodesics

Soon after the Big Bang, the expansion of the universe slowed down until at about 10^{-60} seconds the temperature and density were reduced to values allowing for the first geometrical phase transition to occur. In this transition the angular velocity of the primordial *S-particle*, which was inherently present from the beginning, started to manifest as the particle started to follow a curved path with an initial angular velocity ω_0. Simultaneous to the ejection of the *S-particle*, other particle was ejected, with the same angular velocity but with opposite direction of rotation. Both particles, together with the space time mesh (which is rotating with a constant angular velocity Ω in counter-clockwise direction), define a symmetrical surface of a right-angled-cylinder. The co-rotating and the counter-rotating *S-particles*, relative to the space-time rotation, follow with time helical paths around the cylindrical surface.

In our study, we shall adopt the variational principle as guiding fundamental principle and the "relative space of rotating disks" introduced by Cattaneo [3] and developed by Rizzi and Ruggiero [4] as general physical system of reference. In this approach, the relative space of rotating disk allows for a well-defined procedure for space and time measurements that can be performed by an observer in a rotating frame while being reduced to the local standard space-time measurements. It considers the world lines of each particle in the rotating system as time-like helixes (whose pitch depends on Ω, which is a constant), wrapping around the cylindrical surface with radius r = const.; $r \in [0, R]$. These helixes fill, without intersection, the whole space-time region defined by $r \le R < c/\Omega$, they constitute a time-like congruence Γ which defines the rotating frame F_{rot} at rest with respect to the disk. The lines of Γ constitute the trajectories of the "space-time isometry" and suggest a procedure to define an extended 3-space "relative space". Rizzi and Ruggiero [4] consider this space as the only space having an actual physical meaning from an operational point of view and they assert that it can be identified with the physical space of a rotating platform. In this space, an observer can perform measurements of space and time that coincide everywhere with the local rest frame of the rotating disk.

Consider the space-time continuum of the *S-particles* in M_4 as having a physically admissible system of coordinates x^0, x^1, x^2, x^3 where $x^0 = ct$ is the time coordinate and x^i (i = 1, 2, 3) are the space coordinates. The line-element in Riemannian geometry is then given by,

$$\mathrm{d}s^2 = g_{\mu\nu}\mathrm{d}x^\mu \mathrm{d}x^\nu \text{. (The summation is extended for } \mu, \nu \text{ from 0 to 3)} \tag{1}$$

The coordinate x^0 can be interpreted as time tracks [3] of the primordial *S-particles*.

These particles constitute the physical system of reference where M_3 forms the spatial space of the particles at any instant of time. The time variable x^0 can be regarded as measured by a clock attached to the particle during its motion. The proper time is τ for the particle measured when the clock is at rest in the rotating frame F_{rot}, while the time t is measured by a clock at rest in an inertial frame (CIF).. Following Ref. [3], a general transformation of coordinates in M_4,

$$x^{\mu'} = x^{\mu'}\left(x^0, x^1, x^2, x^3\right),\ \left(\mu' = 0,1,2,3\right) \tag{2}$$

does not always imply a corresponding change of the reference frame, which indicates that the transformation will leave the coordinate line x^0 unchanged. Therefore, the coordinate x^0 can be considered as describing the world lines of the infinite 3-dimensional space of the *S-particles.*

Consider an inertial frame (CIF) F, parameterized by an adapted set of polar cylindrical coordinates $[x^\mu] = (t, r, \theta, z)$ with a line element given by,

$$\mathrm{d}s^2 = g_{\mu\nu}\mathrm{d}x^\mu \mathrm{d}x^\nu = -c^2\mathrm{d}t^2 + \mathrm{d}r^2 + r^2\mathrm{d}\theta^2 + \mathrm{d}z^2, \tag{3}$$

with its origin located at the centre of the cylinder and its z-axis coinciding with the *z*-axis of the cylinder **Figure 1**, the base of the cylinder is considered as the platform of the cylindrical coordinates that rotates with the space-time mesh and has a constant angular velocity Ω. Two *S-particles* are considered to be ejected simultaneously from a point P on the rim of the cylinder at $t = 0$ with a tremendously high linear velocity v_0, making angles $\pm\alpha$ with the z-direction and having angular velocities $\pm\omega_0 = \pm v_0 \sin\alpha / R$ respectively, *i.e.* one of them co-rotating with the rotation of the base platform and the other counter-rotating, while both are constrained to traveling along the surface of the cylinder. We study the motion of the particles as observed by an observer at rest in the (CIF), F, and by another observer at rest in the local rotating central inertial frame (LCIF) F_{rot}. Consider the co-rotating particle where its position in a polar cylindrical coordinates in the CIF frame is $[x^\mu] = (t, r, \theta, z)$ and its line-element is given by the Minkowski metric, Equation (3).

We are going to make the transformation from the frame F to the rotating frame F′ where the particle will have the coordinates $[x^{\mu\prime}] = (t', r', \theta', z')$. For the coordinate transformation from $[x^\mu]$ to $[x^{\mu\prime}]$, the world line ϒ in the two coordinates is given by the following set of equations:

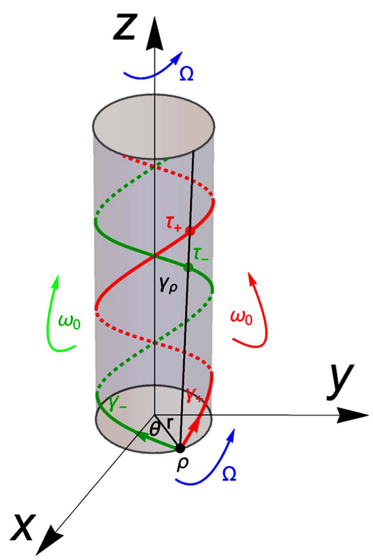

Figure 1. The world lines of the co-propagating and counter propagating *S-particle* with respect with space-time. Υ_P is the world line of a point P on the rim of the base of the cylinder rotating with the angular velocity of space-time. The first intersection of Υ_+ and Υ_- with Υ_P are shown at time τ_+ and τ_- respectively, for one round trip as measured by an observer at rest in the rotating frame (LCIF) F'.

$$\Upsilon \equiv \begin{cases} x^0 = ct \\ x^1 = r \\ x^2 = \theta \\ x^3 = z \end{cases}, \quad \Upsilon' \equiv \begin{cases} x^{0'} = ct' \\ x^{1'} = r' \\ x^{2'} = \theta' + \Omega t' \\ x^{3'} = z' + u_0 t' \end{cases}, \tag{4}$$

where, $u_0 = v_0 \cos\alpha$. The differential elements will be transformed as:

$$\begin{cases} \mathrm{d}x^0 = c\mathrm{d}t \\ \mathrm{d}x^1 = \mathrm{d}r \\ \mathrm{d}x^2 = \mathrm{d}\theta \\ \mathrm{d}x^3 = \mathrm{d}z \end{cases} \to \begin{cases} c\mathrm{d}t' \\ \mathrm{d}r' \\ \mathrm{d}\theta' + \Omega \mathrm{d}t' \\ \mathrm{d}z' + u_0 \mathrm{d}t' \end{cases}. \tag{5}$$

Hence, we obtain in the rotating frame F' the following metric:

$$\mathrm{d}s'^2 = \left(-c^2 + r'^2\Omega^2 + u_0^2\right)\mathrm{d}t'^2 + \mathrm{d}r'^2 + r'^2\mathrm{d}\theta'^2 + \mathrm{d}z'^2 + 2\Omega r'^2\mathrm{d}\theta'\mathrm{d}t' + 2u_0\mathrm{d}z'\mathrm{d}t'. \tag{6}$$

The metric tensor (after dropping the dashes for simplicity) is given by:

$$g_{\mu\nu} = \begin{pmatrix} -\left(c^2 - r^2\Omega^2 - u_0^2\right) & 0 & \Omega r^2 & u_0 \\ 0 & 1 & 0 & 0 \\ \Omega r^2 & 0 & r^2 & 0 \\ u_0 & 0 & 0 & 1 \end{pmatrix} \tag{7}$$

In order to obtain the geodesic equations and hence the equation of motion of the *S-particle*, consider the Lagrangian $L\left(\dot{x}^\rho, x^\rho\right) \equiv 1/2\, g^\rho_{\mu\nu}\left(x^\rho\right)\dot{x}^\mu \dot{x}^\nu$ which is a function of the independent variables $\dot{x}^\rho, x^\rho$, where the dots denote differentiations with respect to an affine parameter that can be the proper time τ (which in our case $\tau = t$). Applying the procedure of the calculus of variation [5], we obtain from the above Lagrangian the Euler-Lagrange equations, given by,

$$\mathrm{d}/\mathrm{d}\tau\left(\partial L/\partial \dot{x}^\rho\right) - \partial L/\partial x^\rho = 0 \quad \left(\rho = 0,1,2,3\right). \tag{8}$$

Substituting the Lagrangian in Equation (8), we obtain the affinely parameterized geodesic equation,

$$\ddot{x}^\rho + \Gamma^\rho_{\mu\nu}\dot{x}^\mu \dot{x}^\nu = 0, \tag{9}$$

where $\Gamma^\rho_{\mu\nu}$ is the connection coefficient. Using the metric of the rotating frame Equation (7), the Lagrangian becomes:

$$L\left(\dot{x}^\rho, x^\rho\right) \equiv 1/2\left[-\left(c^2 - \Omega^2 r^2 - u_0^2\right)\dot{t}^2 + \dot{r}^2 + r^2\dot{\theta}^2 + \dot{z}^2 + 2\Omega r^2\dot{\theta}\dot{t} + 2u_0\dot{z}\dot{t}\right] \tag{10}$$

Substituting the above equation in the Euler-Lagrange Equation (8), we obtain the following geodesic equations for the co-rotating *S-particle*:

The equation for the *t*-coordinate,

$$\mathrm{d}/\mathrm{d}t\left(\partial L/\partial \dot{t}\right) - \partial L/\partial t = 0,$$

$$\ddot{t} = 0 \tag{11}$$

- The equation for the *r*-coordinate,

$$\mathrm{d}/\mathrm{d}t\left(\partial L/\partial \dot{r}\right) - \partial L/\partial r = 0,$$

$$\ddot{r} = \Omega^2 r + r\dot{\theta}^2 + 2\Omega r\dot{\theta} \quad (12)$$

- The equation for the θ-coordinate,

$$\mathrm{d}/\mathrm{d}t\left(\partial L/\partial\dot{\theta}\right) - \partial L/\partial\theta = 0\,, \quad (13)$$

$$r\ddot{\theta} = -2\dot{r}\dot{\theta} - 2\Omega\dot{r}$$

- The equation for the z-coordinate,

$$\mathrm{d}/\mathrm{d}t\left(\partial L/\partial\dot{z}\right) - \partial L/\partial z = 0\,,$$

$$\ddot{z} = 0\,. \quad (14)$$

Multiplying by the mass m of the *S-particle* results in the following spatial equations of motion:

$$m\ddot{r} = m\Omega^2 r + mr\dot{\theta}^2 + 2m\Omega r\dot{\theta}$$

$$mr\ddot{\theta} = -2m\dot{r}\dot{\theta} - 2m\Omega\dot{r}$$

$$m\ddot{z} = 0\,.$$

By rearranging the different terms and substituting the value of $\dot{\theta}$ in the R. H. S., we finally get the following equations of motion in the vector form:

$$m\left[\ddot{r} - 2r\dot{\theta}^2\right]\bar{\boldsymbol{e}}_r = \left[mr\Omega^2 + 2m\Omega r\omega_0\right]\bar{\boldsymbol{e}}_r\,, \quad (15)$$

$$m\left[r\ddot{\theta} + 2\dot{r}\dot{\theta}\right]\bar{\boldsymbol{e}}_\theta = \left[-2m\Omega\dot{r}\right]\bar{\boldsymbol{e}}_\theta\,, \quad (16)$$

$$m\ddot{z}\bar{\boldsymbol{e}}_z = 0\bar{\boldsymbol{e}}_z \quad (17)$$

The L. H. S. of the equations are the inertial forces (radial, angular and axial components), while the R. H. S. are the centrifugal and Coriolis forces.

The last equations can be put in one compact form with vector notations in 3-dimensional Cartesian coordinates as [6]:

$$m\mathrm{d}^2\boldsymbol{r}/\mathrm{d}t^2 = -m\boldsymbol{\omega}_{\text{co-}} \times \left(\boldsymbol{\omega}_{\text{co-}} \times \boldsymbol{r}\right) - 2m\boldsymbol{\omega}_{\text{co-}} \times \left(\mathrm{d}\boldsymbol{r}/\mathrm{d}t\right), \quad (18)$$

$$\boldsymbol{r} = \left(x, y, z\right),\ \ \boldsymbol{\omega}_{\text{co-}}\left(0, 0, \omega\right),\ \ \boldsymbol{\omega}_{\text{co-}} = \boldsymbol{\Omega} + \boldsymbol{\omega}_0\,.$$

Equations (15), (16), (17) and (18) are the equations of motion of the co-rotating *S-particle* in the rotating frame of reference. However, since the motion is restricted to the surface of the cylinder with radius R = constant and $\dot{r} = 0$, the only force on the *S-particle* is the centrifugal force and hence, the last term in Equation (18) will vanish. Similarly, the counter-rotating *S-particle* will only feel the centrifugal force but in the opposite direction. This simulates an attractive generated force acting on the co-rotating particle, and a repulsive generated force acting on the counter-rotating particle.

With further expansion and cooling of the universe, at about 10^{-40} seconds, the radius of the cylinder will start to increase as a function of time, and a second geometrical transition occurs where the motion of the *S-particles* is transformed from a cylindrical shape to a conical one.

Consider the expansion as approximately linear in the radial direction, and transform the coordinates of the position of the *S-particles* as seen by an observer at rest in the frame (CIF)F, $[x^\mu] = (t, r, \theta, z)$, to a rotating frame (LCIF) F$''$ where the observer is at rest and the coordinates of the particle are $[x^{\mu}{''}] = (t'', r'',$

θ'', z'). The world-line Υ of the co-propagating *S-particle* will be given in the two frames by the following set of equations:

$$\Upsilon_{\text{co-}} \equiv \begin{cases} x^0 = ct \\ x^1 = r(t) \\ x^2 = \theta \\ x^3 = z \end{cases}, \quad \Upsilon''_{\text{co-}} \equiv \begin{cases} x^{0''} = ct'' \\ x^{1''} = r(t'') \\ x^{2''} = \theta'' + \Omega t'' \\ x^{3''} = z'' + u_0 t'' \end{cases}, \tag{19}$$

while the differential elements will be transformed as:

$$\begin{cases} \mathrm{d}x^0 = c\mathrm{d}t \\ \mathrm{d}x^1 = \mathrm{d}r \\ \mathrm{d}x^2 = \mathrm{d}\theta \\ \mathrm{d}x^3 = \mathrm{d}z \end{cases} \to \begin{cases} c\mathrm{d}t'' \\ \mathrm{d}r''(t'') \\ \mathrm{d}\theta'' + \Omega \mathrm{d}t'' \\ \mathrm{d}z'' + u_0 \mathrm{d}t'' \end{cases} \tag{20}$$

The Minkowski metric will be given in the new frame F" by:

$$\begin{aligned} \mathrm{d}s''^2 = &-\left(c^2 - \Omega^2 r''^2 - u_0^2\right)\mathrm{d}t''^2 + \mathrm{d}r''^2 + r''^2\mathrm{d}\theta''^2 + \mathrm{d}z''^2 \\ &+ 2\Omega r''^2 \mathrm{d}\theta''\mathrm{d}t'' + 2u_0 \mathrm{d}z''\mathrm{d}t'' \end{aligned} \tag{21}$$

The metric tensor is as given in Equation (7), and therefore the Lagrangian is the same as that in Equation (10). Hence, the geodesics and the equations of motion of the *S-particles* are the same as given by Equations (15), (16) and (17), but in the new rotating frame of reference F", the Coriolis force will appear since now the radial coordinate depends on time.

3. The World Lines of *S-Particles* and Time Difference

In the previous section, according to Refs. [3] [4], we have mentioned that the relative space of rotating disks allows for a well-defined procedure for space and time measurements that can be performed by an observer in a rotating frame. It considers the world lines of each particle in the rotating system as time-like helixes, wrapping around the cylindrical surface with radius R = constant and constitutes a time-like congruence Γ which defines the rotating frame F_{rot} at rest with respect to the disk (see the detailed discussions in Ref. [3] [4]). Let us consider a point P on the rim of the base of the cylinder (see **Figure 1**), which is confined to rotate in a circular path along the rim of the base platform with an angular velocity Ω and where z is constant. The metric will be given by [7],

$$\mathrm{d}s^2 = -c^2\mathrm{d}t^2 + \mathrm{d}r^2 + r^2\mathrm{d}\theta^2 . \tag{22}$$

With respect to (CIF) frame F, of which the radius of the base is R and that rotates with angular velocity Ω, the world-line Υ_{p} of p is,

$$\Upsilon_{\mathrm{p}} \equiv \begin{cases} x^0 = ct \\ x^1 = r = R \\ x^2 = \theta = \Omega t \end{cases} . \tag{23}$$

The proper time read by a clock at rest in the rotating frame after one period of rotation is given by [8],

$$\tau = 1/c\int|\mathrm{d}s| = 1/\Omega\sqrt{1-\beta^2}\int\mathrm{d}\theta\,, \tag{24}$$

where, $\beta = \Omega R/c$ and the integration is over $\pm\theta$ from 0 to $\pm 2\pi$.

Consider that two *S-particles* were ejected simultaneously from the point p on the rim of the cylinder's base at time $t = 0$ when $\theta = 0$ and $z = 0$, and that their angular velocities were respectively, in the vector form $\boldsymbol{\omega}_+ = \boldsymbol{\omega}_{\text{co}-} = (\Omega + \omega_0)\boldsymbol{e}_z$ and $\boldsymbol{\omega}_- = \boldsymbol{\omega}_{\text{counter}-} = (\Omega - \omega_0)\boldsymbol{e}_z$. The world lines of the co-rotating and the counter-rotating particles as seen by an observer at rest in the (CIF) frame F is given respectively by,

$$\Upsilon_{\text{co-}} = \Upsilon_+ \equiv \begin{cases} x^0 = ct \\ x^1 = r = R \\ x^2 = \omega_+ t \\ x^3 = u_{0+}t \end{cases}, \text{ where } \begin{cases} \mathrm{d}x^0 = c\mathrm{d}t \\ \mathrm{d}x^1 = 0 \\ \mathrm{d}x^2 = \omega_+\mathrm{d}t \\ \mathrm{d}x^3 = u_{0+}\mathrm{d}t \end{cases}, \tag{25}$$

$$\Upsilon_{\text{counter-}} = \Upsilon_- \equiv \begin{cases} x^0 = ct \\ x^1 = r = R \\ x^2 = \omega_- t \\ x^3 = u_{0-}t \end{cases}, \text{ where } \begin{cases} \mathrm{d}x^0 = c\mathrm{d}t \\ \mathrm{d}x^1 = 0 \\ \mathrm{d}x^2 = \omega_-\mathrm{d}t \\ \mathrm{d}x^3 = u_{0-}\mathrm{d}t \end{cases}, \tag{26}$$

where the signs (+) and (−) hold for the co-rotating and counter-rotating *S-particles*.

The values of the angular velocities of the two particles along the z-direction are: $\omega_\pm = \Omega \pm \omega_0$, while $u_{0\pm} = v_0\cos(\pm\alpha) = u_0$.

The angles $\theta_\pm$ corresponding to a round trip by the two particles will be given by [8],

$$\theta_\pm = \pm 2\pi\Omega/(\omega_\pm - \Omega)\,. \tag{27}$$

Replacing the angular velocities by the dimensionless velocities $\beta = \Omega R/c$ and $\beta_\pm = \omega_\pm R/c$, gives us for the values of $\theta_\pm$ after one period of rotation the following expression,

$$\theta_\pm = \pm 2\pi\beta/(\beta_\pm - \beta)\,. \tag{28}$$

The proper time τ spent by each rotating *S-particle* measured by an observer at rest in the rotating frame will be given by,

$$\tau_\pm = \frac{1}{c}\int_{\gamma_\pm}|\mathrm{d}s| = \frac{1}{\Omega}\left(\sqrt{1-\frac{\omega_\pm^2R^2}{c^2}-\frac{u_0^2}{c^2}}\right)\int\mathrm{d}\theta\,. \tag{29}$$

Substituting for the value of the integration, the result of $\theta_\pm$ for one period of rotation given by Equation (27), we obtain:

$$\tau_\pm = \pm 2\pi\left(\sqrt{1-\frac{\omega_\pm^2R^2}{c^2}-\frac{u_0^2}{c^2}}\right)\Big/(\omega_\pm - \Omega) \tag{30}$$

Since $u_0 = v_0\cos\alpha$ and $\omega_0 R = v_0\sin\alpha$, then we replace u_0 by $\omega_0 R\cot\alpha$ and hence if we take α for simplicity to be equal to 45˚, then $u_0 = \omega_0 R$.

In terms of the dimensionless velocities, we get from Equation (30) the following expression,

$$\tau_{\pm} = \pm \frac{2\pi\beta}{\Omega} \frac{\sqrt{1-\beta_{\pm}^2-\beta_0^2}}{\beta_{\pm}-\beta}, \text{ (where } \beta_0^2 = u_0^2/c^2 \text{)} \tag{31}$$

It is clear that the time spent by each particle in a round trip depends upon β and $\beta_{\pm}$ *i.e.* on both the angular velocity of space-time Ω and the *S-particle's* angular velocities $\pm\omega_0$. The time elapsed between the two particles in one round trip is given by,

$$\Delta\tau = \tau_{+} - \tau_{-} = \frac{2\pi\beta}{\Omega}\left[\frac{\sqrt{1-\beta_{+}^2-\beta_0^2}}{\beta_{+}-\beta} + \frac{\sqrt{1-\beta_{-}^2-\beta_0^2}}{\beta_{-}-\beta}\right], \tag{32}$$

or approximately,

$$\Delta\tau \approx 2\pi\beta/\Omega\left[\left(1-1/2\left(\beta_{+}^2+\beta_0^2\right)\right)/\left(\beta_{+}-\beta\right)+\left(1-1/2\left(\beta_{-}^2+\beta_0^2\right)\right)/\left(\beta_{-}-\beta\right)\right]. \tag{33}$$

If we consider $\beta'_{\pm}$ to be the velocities of the rotations of the particles as measured in any Minkowski inertial frame, locally co-moving with the rim of the base of the cylinder (LCIF) or generally in any locally co-moving inertial frame (provided that each (LCIF) is Einstein-synchronized [8]) the Lorentz Law of velocity addition gives the following relations between $\beta'_{\pm}$ and $\beta_{\pm}$ [9]:

$$\beta_{\pm} = \left(\beta'_{\pm}+\beta\right)/\left(1+\beta'_{\pm}\beta\right). \tag{34}$$

Substituting Equation (34) into Equation (33), and after imposing Einstein synchronized condition ($\beta'_{+} = -\beta'_{-}$) which implies that the particles should have equal relative velocities in opposite directions in every (LCIF) [8], we get:

$$\Delta\tau \approx \left(2\pi\beta^2\right)/\Omega\left(1-\beta^2\right)\left[\left(\beta_{+}'^2+\beta^2-2\beta_{+}'^2\beta^2-\beta_0^2\left(1-\beta_{+}'^2\beta^2\right)\right)/\left(1-\beta_{+}'^2\beta^2\right)\right]. \tag{35}$$

Since, $\beta_{+}'^2\beta^2 \ll 1$, then we get the simplified expression for $\Delta\tau$:

$$\Delta\tau \approx \left(2\pi\beta^2\right)/\Omega\left(1-\beta^2\right)\left[\beta_{+}'^2+\beta^2-\beta_0^2\right]. \tag{36}$$

In terms of the angular velocities, we get the following approximate expression:

$$\Delta\tau \approx \left(4\pi\beta^4\right)/\Omega\left(1-\beta^2\right)\left[1+\omega_0/\Omega\right], \tag{37}$$

where ω_0 may vary from 0 up to Ω (*i.e.* $0 < \omega_0 < \Omega$).

The upper limit of the S-particle's angular velocity ω_0 is the space-time rotation velocity Ω, which cannot be exceeded.

4. Modification of Relativistic Sagnac Time Difference

The first experiment to report the effect of rotating beams of light on space-time, was performed by Sagnac in 1913 [10]. He built an optical interferometer on a turntable and let two beams from a source of electromagnetic waves on the table travel in opposite directions along a closed path with the same velocity (in absolute value) relative to the motion of the turntable. The two beams took different times for a complete round trip depending on their velocity relative to the turntable. This time difference was reported as a phase shift detected by the interferometer and has always the same value, given by [8],

$$\Delta t = 4\boldsymbol{\Omega}\cdot\boldsymbol{S}/c^2\ , \tag{38}$$

where $\boldsymbol{\Omega}$ is the angular velocity vector of the turntable and $\boldsymbol{S}$ is the vector associated with the area enclosed by the path traveled by the beams. The experiment was repeated by many investigators using different types of beams [11] [12] where it turned out that Equation (38) is valid for any beam, electromagnetic or material, regardless to its type of entities (electromagnetic waves, acoustical waves, electron beams, neutron beams etc.). Therefore, the universality of Equation (38) was confirmed and the equation afterwards was known as the "Sagnac effect". The proper time difference between two beams co- and counter-propagating with respect to the turntable and confined to travel a circular path around the rim of the rotating disk of the interferometer, was calculated on the base of relativistic kinematics that is considered as the relativistic Sagnac time difference [8], given by,

$$\Delta\tau = \left(\frac{4\pi\beta^2}{\Omega}\right)\frac{1}{\sqrt{1-\beta^2}}\ , \tag{39}$$

where Ω is the angular velocity of the turntable and β is the relative velocity $\Omega R/c$.

If we now attempt to incorporate this Formula (39) into the previously obtained formula for the time difference between the *S-particle* and its antiparticle (37), then we reach the following expression:

$$\Delta\tau = \frac{4\pi\beta^4}{\Omega\left(1-\beta^2\right)}\left[1+\frac{\omega_0}{\Omega}\right] = \frac{4\pi\beta^2}{\Omega}\frac{1}{\sqrt{1-\beta^2}}\left[\frac{\beta^2}{\sqrt{1-\beta^2}}\left(1+\frac{\omega_0}{\Omega}\right)\right], \tag{40}$$

which can be considered as a modified-relativistic Sagnac time difference. Contrarily to Equation (39), in Equation (40) the time difference does not depend only on the space-time angular velocity Ω, but also on the angular velocities of the co-(counter-) rotating *S-particles* ω_0.

5. The Dual Universe and Dark Energy

Equation (36) gives the time difference between the two *S-particles* in one round trip around the surface of the cylinder, while the point p on the rim of the base goes from $\theta = 0$ to $\theta = 2\pi$. This time difference can be seen from the intersection of the world lines of the two *S-particles* ($\Upsilon_\pm$) with the world line of the point p (Υ_p), **Figure 1**, with more round trips the time difference will increase linearly.

For n round trips, we get the following equation for the time difference between the two particles:

$$\Delta\tau_n = \left(2\pi n\beta^2\right)/\Omega\left(1-\beta^2\right)\left[\beta_+'^2+\beta^2-\beta_0^2\right],\ (\text{where}\quad n=1,2,\cdots,\infty\ ). \tag{41}$$

If the velocity of the particles in the z direction is $u_0 = v_0\cos\alpha$, then, provided that the proper time is the same as the real time ($\tau = t$), the difference in the location of the two particles along the z direction is:

$$\Delta L_n = v_0 \cos\alpha \cdot (\Delta \tau_n). \tag{42}$$

After an infinitesimal fraction of a second from the "Big Bang" when the universe was filled with (anti-) *S-particles*, these primordial particles gave rise to the formation of the known fundamental and anti-fundamental particles [1]. The above separation between the particles and their counterparts, thus led to the formation of two separate universes *i.e.* our universe and its dual counterpart in different spatial locations. The early expansion of the galaxies in our universe by a force propelling them apart can be explained as a remnant of the initial impetus of the "Big Bang". The following recession was slowing down because of the gravitational attraction of different parts of the universe to each other. We can assume that the formation of the antimatter universe followed evolutionary stages similar to those of our universe (*i.e.* formation of anti-atoms from anti-quarks and anti-leptons etc.), but in a later time, as the expansion and cooling of the anti-matter universe followed a slower rate due to the lagging in time between the formation of the two universes (see **Figure 2**). Moreover, following the formation of clusters of antimatter, an anti-gravitational force may have been built up, exerting a repulsive force upon our universe. This anti-gravitational force took around eight to ten billion years to be built up to its maximum value, which might explain why at this time the expansion of our universe started to accelerate [13] [14].

The counter rotation of the antimatter universe with respect to our universe's

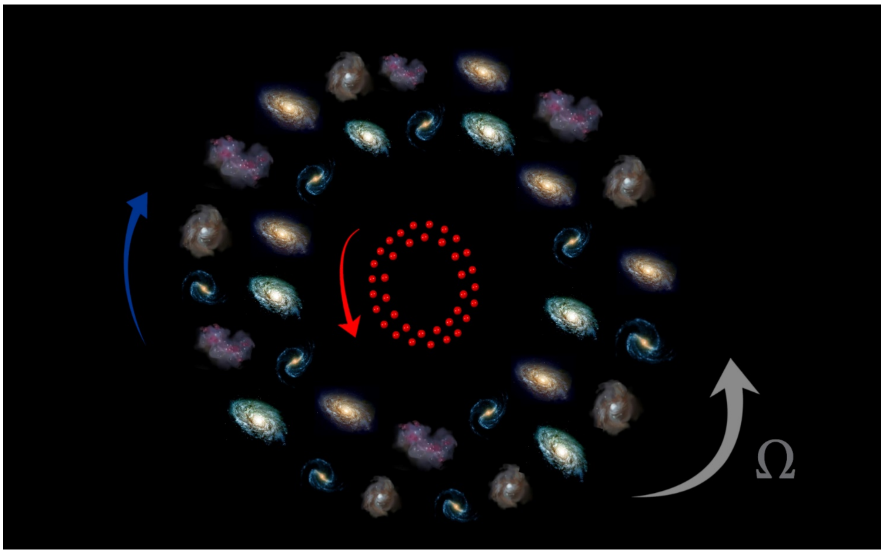

Figure 2. An artistic illustration of a cross-sectional area for the dual universe with our universe in blue and its antimatter counterpart in red, earth being a mere point in between the (clusters of) galaxies. Ω is the angular velocity of the space-time mesh and as can be seen from the figure, our universe and its dual counterpart are in opposite rotation. The dual universe was initiated about 13.8 billion years ago following the Big Bang, which was located in the middle point in the figure.

rotation might exert a repulsive gravity (negative gravity) that affects our universe. The opposite course of rotation of our dual universe affects our universe and generates antigravitational-waves that penetrate our universe leading to a negative like-curvature in the shape of the space-time mesh around our galaxies pushing them outwards. This repulsive force together with the expansion of the space time mesh, may be referred to as caused by an exotic dark energy, that permeates and affects all rotating galaxies, clusters of galaxies or any rotating object in our universe. Before the clusters of antimatter in the antimatter universe started to manifest as exerting a powerful and strong anti-gravitational force upon our universe, pushing it to expand and accelerate away, the expansion showed a slowdown because of the gravitational attraction caused by matter in our universe. The mutual attraction between all matter and dark matter in our universe led to the building up of a force working against the expansion of the space time mesh and the repulsive force of the antimatter universe that resides in closer proximity in sphere around the so called singular point, **Figure 2**.

The idea that the attractive force opposing the expansion would ultimately be striving to stop it, was recently contradicted by clear evidence from observational data collected by NASA's scientists about the behaviour of supernovae [15], which confirmed the accelerated expansion of our universe. Moreover, the data showed that the farthest galaxies from the perspective of our own (Milky Way) galaxy are accelerating at a faster pace than the ones nearer to us. The reason for this may be due to the fact that the density of matter in the outer layers or at the edge of our universe is less, resulting in a weaker attractive force to counteract the repulsive force of the antimatter universe.

It is worth mentioning here that the repulsive anti-gravitational force from the clusters of antiparticles in the antimatter universe as a whole upon our universe and which is due to the opposite course of rotation of the two universes is completely different from the electrostatic repulsive force between similarly charged particles or the repulsive force between similar magnetic poles. It is also different from that due to a possible gravitational or anti-gravitational interaction between individual matter and anti-matter or particle and its anti-particle, that might violate the CPT invariance, the theory of general relativity or the law of energy conservation. It is rather, a kind of negative gravity that affects our universe as a whole, due to opposite course of rotation of the dual anti-universe relative to ours. The effect of this opposite rotation can generate antigravitational-waves that penetrate our universe leading to a negative like-curvature in the shape of the space-time mesh around our galaxies pushing them outward and causing the accelerated expansion of our universe. The continuous anti-gravitational waves that permeate and fill our universe might cause a constant background ripples (space-fluctuations) in the space of our solar system.

6. Proposed Experiments

As there is no experimental method available through which the antimatter universe and dark energy can be observed directly, their existence can only be verified by detecting and measuring their influence on our universe. In order to detect anti-gravitational waves originating from our dual counter-universe, we could install two of the most sensitive apparatus available for gravitational wave detection (e.g. LIGO type), and direct one of them towards the most distant galaxies in our universe, while positioning the other at 180 angular degrees on the opposite side of the earth, in order to detect vertical (anti-) gravitational waves falling upon them. It is imperative that these detectors are very sensitive in order to register the even weakest signal received by the receptors. In fact the earth, together with its solar system, is a mere point (see **Figure 2**) with respect to the size of the universe as a whole. As the dual-antimatter universe is located at a tremendous distance from our planet, the anti-gravitational waves that reach us are very weak, even though these waves as a whole are strong enough to cause a large repulsive force on our universe. Gravitational and anti-gravitational waves are received by our detectors as tiny ripples caused by distortions in the space-time fabric. We seek to detect these minuscule ripples in order to prove the existence of the gravitational and anti-gravitational waves. Subsequently, for the duration of one earth's rotation, signals should be collected simultaneously from both detectors and the data should be compared and analyzed, in order to discover a clear difference in results at a certain instant of time. This might indicate the detection of anti-gravitational waves arriving from our universe's dual counterpart. The falling of these waves on the interferometer detector at the observatory causes differential changes in the lengths of the arms of the interferometer, which are placed perpendicular to each other. These differential changes can be sensed most accurately by laser interferometers. When a gravitational wave falls on one arm of the interferometer it is contracted in length while the second arm is stretched (its length is increased). In the case of an anti-gravitational wave the opposite happens as the first arm is stretched while the second is contracted, therefore the measurements should be taken simultaneously. The change in the length of the passage of the two optical beams, causes a phase shift which is detected by the interferometer optical detector.

An experiment could be carried out with similar ground-based interferometers, but with higher sensitivities, in order to detect a possible background space fluctuation and hence, confirm the existence of a universe counter to ours. In this case, the wavelengths of the anti-universe waves received should have different values than those detected by the LIGO team for gravitational waves in the 2015 experiment [16].

The project "Laser Interferometer Space Antenna (LISA)" which is intended for building a space-based gravitational wave interferometer, will be completed and launched in the 2030's. The gravitational interferometer will fly along an earth-like heliocentric solar orbit with flexible length arms (about 2.5 million kilometer long), which would enable the detection of space disturbances caused by a gravitational or anti-gravitational wave passing the interferometer with much more sensitivity (about one part per 10^{20} strain sensitivity) than any ground-based gravitational wave interferometer, while covering the low frequency band of gravitational wave spectrum.

A careful and accurate analysis of the intensities of signals that might be received from (anti-) gravitational waves by ground and space-based interferometers, could shed a light upon the origin of disturbances in the space-time fabric and provide information on the distance between our universe and its dual counterpart.

An experiment (a particle anti-particle collision experiment at very high energies), could be done at CERN, to detect and confirm the existence of the hypothesized "*S-particle*" and its anti-particle, that were created in the very early universe immediately following the "Big Bang".

7. Conclusions

In the present article it is shown that the "*S-particle model*" in addition to providing an explanation for the formation of dark matter and the particles of our universe [1], may as well imply the existence of an anti-universe, as a dual counterpart to ours. This antimatter universe may be considered as a negative universe which through co-rotation with space-time is likely to exert a repulsive force on our universe. The repulsive anti-gravitational force from the clusters of antiparticles in the antimatter universe as a whole upon our universe is completely different from the possible gravitational or anti-gravitational interaction between individual matter and antimatter or particle and its antiparticle that might violate the CPT invariance, the theory of general relativity or the law of energy conservation. It is rather, a kind of negative gravity that collectively affects our universe as a whole, due to the opposite course of rotation of the dual counter universe relative to ours. The effect of this opposite rotation can cause anti-gravitational waves that penetrate our universe leading to a negative like-curvature in the shape of the space-time mesh of the vast voids between and around galaxies and cluster of galaxies, pushing them outward and causing the accelerated expansion of our universe.

The anti-gravitational force together with the space-time expansion might be the source of the exotic dark energy in our universe.

In order to testify the existence of the antimatter universe, the article also proposes two sensitive gravitational wave laser interferometric detectors to be erected in opposite locations, in order to measure any difference in the detected signals due to gravity and anti-gravity waves, thus may confirm the presence of a repulsive gravitational waves originating from the antimatter universe. The continuous anti-gravity wave that permeates and fills the space-time of our universe might cause a constant background space fluctuation in the space of our solar system.

Finally, the proposed model might participate in solving two of the greatest mysteries in physics and astrophysics of our times, namely the question why our universe is composed almost entirely of ordinary matter, and the question of the origin of dark energy.

Conflicts of Interest

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

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