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Cause of the Accelerating Rate of Expansion of the Universe

Andrzej Szummer*

Warsaw University of Technology, Faculty of Materials Science and Engineering, Warsaw, Poland

***Corresponding author**: Andrzej Szummer, Warsaw University of Technology, Faculty of Materials Science and Engineering, Warsaw, Poland. E-mail: aszummer@op.pl

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Abstract

The accelerating rate of expansion of the universe has been observed through the increasing velocity of recession of galaxies from one another. However, the cause of this acceleration is still unknown. Based on the hypothesis that the universe is rotating, this study attempts to uncover the cause of this phenomenon through classical mechanics. New arguments justifying the adoption of this hypothesis are presented. The rotation of the universe indicates the influence of two enormous forces - centrifugal force and gravitational force. The difference between these two forces produces an unbalanced resultant force that causes the accelerating rate of expansion. Certain recognized cosmological parameters are used to calculate the acceleration of expansion of the universe, the epoch at which it began, and its temporal evolution.

Keywords: ***Physics of the early universe; Galaxy dynamics; Galaxy formation***

Introduction

Astronomers have discovered that the universe is expanding such that galaxies are drifting away from one another at an accelerated rate [1]. The 2011 Nobel Prize in Physics was awarded for the discovery of this phenomenon through observations of distant supernovae [2]. However, the cause of the acceleration is unknown [3]. Thus far, attempts to explain the cause have been based on the dark energy hypothesis [1, 3-6]. However, dark energy itself remains poorly explained and undiscovered. According to S.Perlmutter “the dark energy evinced by the accelerating cosmic expansion grants us almost no clues to its identity” [1]. In physical cosmology and astronomy, dark energy is assumed to be a hypothetical form of energy that permeates all space, is constant, has negative pressure (repulsive action) that opposes gravity, and causes the accelerating expansion of the universe [3-6]. One of the proposed forms of dark energy is a cosmological constant (λ-Lambda), representing a constant and homogenous energy density filling space. However, the observed and theoretical values of the cosmological constant are disparate; while the observed value is small, the theoretical value is large. This is called the cosmological constant problem [3].

This study operates on the hypothesis that the universe rotates [7-13]. The objective of this research is to analyze the relation of this rotation with the universe’s accelerating rate of expansion.

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The rotation of the universe cannot be directly observed by astronomers because; the observer on Earth would be rotating with the entire universe, and consequently lack a point of reference. This impasse has brought the hypothesis under scrutiny. This study presents new arguments to justify the adoption of this hypothesis. The rotation of the universe implies the influences of two immense forces: centrifugal force and gravitational force [14, 15].

The gravitational force causes all matter in the universe to attract one another. According to Newton's universal law of gravitation, "Everybody in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them." Thus, the gravitational force of attraction F_g between two bodies of masses m_1 and m_2 separated by a distance r is given by the following formula [14, 15]:

$$F_g = G\frac{m_1 m_2}{r^2}$$

Where G is a constant called the universal gravitational constant.

The gravitational force on m_1 is toward m_2, and vice versa. Thus, the force acts along the line joining the centers of mass of the two bodies. This force is a long-range force, and it is inversely proportional to the square of the distance r. Therefore, strongly decreases with the increase in this distance. The gravitational force becomes significant if at least one of the bodies is massive. In fact, it plays a major role in celestial phenomena such as the formation, evolution, and motion of galaxies, stars, and planets.

The centrifugal force acts on every point of the universe rotating about an axis, going through the center of mass of matter. If the position of a given point on a plane perpendicular to the axis of rotation can be determined, the magnitude of the centrifugal force is expressed by the following formula [15]:

$$F_c = m\omega^2 r$$

where:

F_c -is the centrifugal force,

m-is the mass of a body,

r-is the distance of this body from the axis of rotation, and

ω-is the angular velocity of the body.

The concept of centrifugal force can be applied in rotating devices, as well as planetary orbits and galactic motion [15].

Next, the influence of these forces on the expansion of the universe is analyzed using classical mechanics.

Method

Classical mechanics

Classical mechanics is a physical theory describing the motion of macroscopic bodies. The earliest development of this theory (often referred to as Newton mechanics) consisted of the physical concepts employed and the mathematical methods invented by Isaac Newton, Gottfried Wilhelm Leibniz, and others in the 17th century to describe the motion of bodies under the influence of a system of forces [14, 15]. Stars and galaxies are macroscopic bodies, and therefore obey the laws of classical mechanics. For a body governed by classic mechanics, if its present state is known, its future motion can be predicted and its past motion can be traced.

Results

Rotational kinetic energy of the universe

A body rotating about any axis through the center of mass has a rotational kinetic energy E_R, which is the sum of the kinetic energies of its moving parts. According to classical mechanics, the kinetic energy of rotation can be expressed as follows (1) [14, 15]:

$$E_R = \frac{1}{2} I\omega^2 = \frac{1}{4} MR^2\omega^2 \tag{1}$$

where:

ω-angular velocity of the universe.

$I = \frac{1}{2} MR^2$ -moment of inertia of the universe (as a flat disk).

M-mass of the universe.

R-radius of the universe.

The closed [16], rotating and expanding universe is by the centrifugal force significantly influenced. This force caused the universe to lose its spherical shape and become a flat disk. This is also the shape of rotating spiral galaxies, which, like the rotating universe itself, are under the action of local gravitational and centrifugal forces (e.g., Andromeda galaxy, Milky Way galaxy, Whirlpool galaxy M51a).

The critical density of the universe is 0.85×10^{-26} kg/m^3 [17].

The critical density is the energy/mass density at which the universe is flat. In a flat universe, Euclidean geometry is applicable at the largest scale. The hypothesis adopted in this article that the rotating universe is in the shape of a flat disk meets the requirements of Euclidean geometry. The critical density includes three significant forms of energy and mass:

- ordinary matter (baryonic) (4.9%),
- cold dark matter (26.8%),
- and dark energy (68. %).

The mass of ordinary matter is equal: M = 1.5×10^{53} kg [17].

This mass can be converted into energy using Einstein's energy–mass equivalence:

$$E_{OM} = Mc^2 \tag{2}$$

where:

E_{OM}-energy of ordinary matter;

M-mass of ordinary matter;

c-speed of light equal to 2.998×10^8 ms^{-1}

$$E_{OM} = 1.5\times10^{53}\times8.99\times10^{16} = 1.35\times10^{70}\ J = kgm^2s^{-2} \tag{3}$$

The energy of dark matter E_{DM} and the dark energy E_{DE} are equal:

$$E_{DM} = \frac{E_{OM}}{4.9} \times 26.8 = 7.38 \times 10^{70}\, J \tag{4}$$

$$E_{DE} = \frac{E_{OM}}{4.9} \times 68.3 = 1.88 \times 10^{71}\, J \tag{5}$$

If the hypothesis that the universe is a rotating flat disk is true, and assuming, as a first approximation, the kinetic energy E_R of the rotating universe is equal to the dark energy E_{DE} [7], the kinetic energy (equation (1)) will be equal to:

$$E_R = E_{DE} \tag{6}$$

$$E_R = \frac{1}{4} MR^2 \omega^2 = 1.88 \times 10^{71}\, J \tag{7}$$

Where:

M-mass of ordinary matter,

R=4.4 × $10^{26}$$m$ - current radius of the universe [18]

ω-angular velocity of the universe.

Angular velocity of a rotating universe

Equation (7) was used to calculate the current angular velocity ω of the rotating universe. The kinetic energy $E_R = 1.88 \times 10^{71}\, J$, the mass of ordinary matter $M = 1.5 \times 10^{53}\, kg$, and the current radius of the universe $R = 4.4 \times 10^{26}\, m$ [18] (first approximation) were substituted into this equation, which resulted in:

$$\omega^2 = \frac{4E_R}{MR^2} = 0.259 \times 10^{-34} \tag{8}$$

$$\omega = \frac{1}{R}\sqrt{4E_R M^{-1}} = 0.51 \times 10^{-17} \quad rad\ s^{-1} \tag{9}$$

The current angular velocity of the universe's rotation, calculated using classical mechanics, appeared to be of the same order as the angular velocity calculated by Su&Chu [19], who applied an entirely different method, i.e., the analysis of cosmic microwave background anisotropy data (CMBA). These authors constrained the angular velocity to less than:

$$\omega = 10^{-9}\, rad\ yr^{-1} = 3.171 \times 10^{-17}\, rad\ s^{-1} \tag{10}$$

The compatibility of the two results (equations (9) and (10)) indicates the possibility that the universe is rotating.

A significant argument pointing to the rotation of the universe can be made by comparing the angular velocity of rotating galaxies with that of the rotating universe. The rotation of galaxies may imply the rotation of the universe because the initial rotation of the universe may have caused the rotation of galaxies. Galaxies can only form in a rotating universe, and therefore themselves rotate since the instance of their formation.

The current angular velocity of the rotating Milky Way can be calculated using [14]:

$$\omega_g = \frac{v_g}{r_g} = \frac{2.2 \times 10^5}{0.87511^{21}} = 2.5140 \times 10^{-16}\, rad\ s^{-1} \tag{11}$$

Where:

ω_g-angular velocity of the rotating Milky Way galaxy;

v_g-typical stellar orbital speed of the Milky Way equal to $220 \pm 10 km/s = (2.2 \times 10^5) m/s$ [20],

r_g-radius of the Milky Way equal to approximately $92.5 \times 10^3 l.yrs. = 0.925 \times 10^5 \times 9.4607 \times 10^{15} = 8,751 \times 10^{20} m$ [21].

The current angular velocity of the rotating Milky Way (equation (11)) is larger than that of the rotating universe (equation 9). However, owing to the expansion of the universe, its radius continues to decelerate the angular velocity of its rotation (equation 9). This means that this velocity was greater in the past. In contrast, due to the lack of expansion, the angular velocity of the Milky Way has remained unchanged, i.e., it is the same as in the past. Hence, at a certain epoch in the past, the angular velocities of the rotating universe and rotating Milky Way were the same. To calculate the radius R_E of the universe when its angular velocity was equal to the angular velocity of the Milky Way, the angular velocity of the rotating Milky Way is substituted in equation (9), leading to equation (11):

$$R_E = \frac{1}{\omega_g}\sqrt{\frac{4E_R}{M}} = 0.6495 \times 10^{25} m \qquad (12)$$

Where:

R_E-radius of the rotating universe when its angular velocity was equal to that of the Milky Way's rotation was equal;

$\omega_g = 2.5140 \times 10^{-16} s^{-1}$ -angular velocity of the Milky Way; $E_R = 1.88 \times 10^{71} J$ - kinetic energy of the rotating universe; $M = 1.5 \times 10^{53} kg$ -mass of ordinary matter in the universe.

As the radius R_E is known, the epoch t at which the angular velocities of the Milky Way and the universe were equal can be calculated by first approximation:

$$\frac{R}{t_o} = \frac{R_E}{t} \qquad (13)$$

$$t = \frac{R_E}{R} t_o \cong 204 \times 10^6 yrs. \qquad (14)$$

Where:

$R=10.4\times10^{26}$ [17] - the current radius of the universe,

t_o=13.8 billion years [22] - the age of the universe.

This epoch occurred approximately 204 million years or $(204 \times 10^6 yrs.)$ after the Planck epoch or the big bang singularity, i.e., approximately 13.6 billion years. Next, this epoch will be compared with the age of the Milky Way.

The age of the Milky Way can be determined by calculating the age of the oldest stars in it. The ages of the oldest stars in the Milky Way are 12.5 ± 3 billion years [23, 24]. This age is compatible with the epoch (13.6 billion years ago) in which the angular velocity of the rotating universe was equal to that of the rotating Milky Way. This means that, at the time of formation of the Milky Way, its angular velocity was the same as that of the rotating universe. Hence, this compatibility justifies the adoption of the hypothesis of a rotating universe in this study.

Another example confirming the rotation of the universe comes from comparing the angular velocity of rotation of the distant galaxy MACS1149-JD1 (hereafter JD1), with that of the rotating universe. The redshift for this galaxy is $z = 9.1$. The typical stellar orbital speed of JD1 is about 50 kilometers per second [25], and its diameter at only 3,000 light-years [26], is much smaller than that of the Milky Way. Let us calculate the angular velocity of the rotating galaxy JD1 like to the Milky Way (eq. (11)):

$$\omega_{(JD1)} = \frac{v_{(JD1)}}{r_{(JD1)}} = \frac{0,5\times10^{5}}{0.015\times10^{5}\times9.4507\times10^{15}} = 3.5236\times10^{-15}s^{-1} \qquad (15)$$

where:

$\omega(JD1)$-angular velocity of the rotating JD1 galaxy;

$v(JD1)$-typical stellar orbital speed of the JD1 galaxy equal to $50\pm10\{km/s\}=(0.5*10^{5})\{m/s\}$ [25]

$r(JD1)$–radius of the JD1 galaxy equal to approximately

$$1.500\ l.yrs.\ =\ (0.015\times105\times9.4607\times1015m)$$ [26],

The angular velocity of the rotating JD1 galaxy (equation 15) is larger than that of the rotating universe (equation 9). As the universe expands, its radius keeps increasing. This causes to decelerate the angular velocity of its rotation (equation 9), which was higher in the past. This means that at a certain epoch in the past, the angular velocities of the rotating universe and rotating JD1 galaxy were the same. To calculate the radius R_{UJ} of the universe when its angular velocity was equal to the angular velocity of JD1 galaxy, the angular velocity of the rotating JD1 (equation 15) is substituted to equation (9), leading to equation (16):

$$R_{UJ} = \frac{1}{\omega_{(JD1)}}\sqrt{\frac{4E_R}{M}} = 0.6354\times10^{24}m \qquad (16)$$

Where:

R_{UJ}-radius of the rotating universe when its angular velocity was equal to that of the rotating JD1 galaxy,

$\omega_{(JD1)} = 3.5236\times10^{-15}s^{-1}$ -angular velocity of the JD1 galaxy,

$E_R = 1.88\times10^{71}J$ -kinetic energy of the rotating universe,

$M = 1.5\times10^{53}kg$ -mass of ordinary matter in the universe.

The epoch t at which the angular velocities of the JD1 galaxy and the universe were equal can be calculated by first approximation:

$$\frac{R}{t_o} = \frac{R_{UJ}}{t} \qquad (17)$$

$$t = \frac{R_{UJ}}{R}t_o = \frac{0.6354\times10^{24}}{4.4\times10^{26}}\times13.8\times10^{9} = 1.9928\times10^{7} \cong 20\times10^{6} \qquad (18)$$

Where:

R_{UJ} -radius of the rotating universe when its angular velocity was equal to that of the rotating JD1 galaxy,

R–the current radius of the universe= $4.4\times10^{26}m$ [17],

t_0 – the age of the universe=13.8 billion years [22].

This epoch occurred approximately 20 million years or $(20\times10^{6}\ \text{yrs.})$ after the Planck epoch or the big bang singularity, i.e., approximately 13.78 billion years ago (Presumed beginning of the formation of the JD1 galaxy).

Next, this epoch will be compared with the age of the JD1 galaxy. This galaxy's age is given by a redshift of z=9.1, which means it is approximately 13.28 billion years old (A fully formed JD1 galaxy emitting light as observed on Earth). This age is compatible with the epoch (13.78 billion years ago) in which the angular velocity of the rotating universe was equal to that of the rotating JD1 galaxy. This means that, at the epoch of formation of this galaxy, its angular velocity was the same as that of the rotating universe. This compatibility is analogous to that of the Milky Way.

This example is one more argument supporting the hypothesis of the rotation of the universe.

The acceleration with which the universe is expanding

Consider a galaxy that has the same mass as the Milky Way. Suppose this hypothetical galaxy is located at a distance equal to the radius of the universe (R) from its the center of mass. Every rotating galaxy, is under the influence of two local forces: the gravitational force Fg related to its mass [14], and the centrifugal force Fc related to its angular velocity of rotation [15], which act on the galaxy in opposite directions:

$$F_g = -G\frac{mM}{R^2} \tag{19}$$

$$F_c = m\omega^2 R = m\frac{4E_R}{MR} \tag{20}$$

where:

$G = 6.67\times10^{-11}\,Nm^2kg^{-2}$ -gravitational constant [15];

$m = 3\times10^{42}\,kg$ -mass of the Milky Way [27];

$M = 1.5\times10^{53}\,kg$ -mass of the universe;

$\omega^2 = 4E_R / MR^2$ -the square of the angular velocity of the universe's rotation; (eq. (8))

$R = 4.4\times10^{26}\,m$ -current radius of the universe;

$E_R = 1.88\times10^{71}\,J$ - kinetic energy of the rotating universe. Substitution of these parameters into equations (19) and (20) gives:

$$F_c = 3.416\times10^{34}\ N \tag{21}$$

$$F_g = 1.55\times10^{32}\ \text{N} \tag{22}$$

Equations (21) and (22) indicate that the centrifugal force of the hypothetical galaxy is currently greater than the gravitational force. The difference between the two forces is the resultant force that causes the accelerated expansion of this galaxy:

$$\Delta F = F_c - F_g = 3.40\times10^{34}\ \text{N} \tag{23}$$

Newton's second law of motion is applied to calculate this acceleration, which states that the acceleration of an body, as produced by a net force, is directly proportional to the magnitude of this force, and inversely proportional to the mass of the body [14]:

$$A=\frac{\Delta F}{m}=\frac{3.404\times10^{34}}{3\times10^{42}}=1.1347\times10^{-R}\{\frac{N}{kg}=\frac{m}{s^2}\} \quad (24)$$

Where:

A-is the acceleration,

ΔF-is the net force,

m-is the Milky Way's mass.

The acceleration of the expansion rate is a function of the radius of the universe R, which is a variable:

$$mA=F_c-F_g=m\frac{4E_R}{MR}-G\frac{mM}{R^2}, \quad (25)$$

$$A=\frac{4E_R}{MR}-G\frac{M}{R^2} \quad (26)$$

Equation (26) indicates that the acceleration of expansion A does not depend on the mass m of the accelerating body therefore this equation is valid not only for a single galaxy but also for the entire universe. Moreover, this equation implies that, as the radius R increases, the acceleration decreases. However, the gravitational force F_g decreases faster than the centrifugal force F_c. The second negative term, representing the gravitational force, is inversely proportional to the second power of the radius of the universe R. Meanwhile, the first positive term of this equation, representing centrifugal force, is inversely proportional to the first power of R. Consequently, as the radius R increases, the centrifugal force decreases more gradually than the gravitational force. This causes the centrifugal force Fc to be consistently greater than the gravitational force F_g **FIG 1**. Hence, the rotating universe is expanding at an accelerating rate. This conclusion in turn demonstrates that the cause of the accelerating expansion of the universe is its rotation.

In equation (26), the acceleration term A must be positive for the expansion of the universe to accelerate. Therefore, in this equation, the centrifugal force must be greater than the gravitational force ($F_c > F_g$):

$$\frac{4E_R}{MR}>\frac{GM}{R^2} \quad (27)$$

$$R_{\min}>\frac{GM^2}{4E_R} \quad (28)$$

Equation (27) is the condition for the expansion of the universe to begin accelerating due to its rotation. R_{min} is the radius when the centrifugal force is equal to the gravitational force **FIG. 1**. When $R = R_{min}$, a balance is established between the centrifugal and gravitational forces. Examples of this balance can be observed in planetary systems and rotating spiral galaxies. During the epoch when the radius of the universe was less than R_{min}, it increased because of the expansion of the primordial universe, which was also caused by the formation of hydrogen and helium atoms, i.e., big bang nucleosynthesis. A huge empty void exists between atomic nuclei and the electrons orbiting them, which causes the atoms to have larger volumes than the constituent elemental particles. When the radius of the universe began to increase beyond than the R_{min}, the universe began to expand at an accelerated rate because the centrifugal force became stronger than the gravitational force. Next, R_{min} is calculated by substituting the cosmological parameters into equation (28):

$$R_{\min}>1.996\times10^{24}\text{ m} \quad (29)$$

A comparison of the radius R_{min} with the current radius of the universe $R = 4.4*10^{26}\{m\}$ helped verify the epoch at which the expansion of the universe began to accelerate:

$$\frac{R}{t_o} = \frac{R_{\min}}{t}, \tag{30}$$

$$t = \frac{R_{\min}}{R} t_o \cong 63\times10^6 \, yrs. \tag{31}$$

Where:

t_0=13.8 billion years - age of the universe [22];

t-instance after the big bang at which the expansion began to accelerate.

The accelerating expansion of the universe began approximately 63 million years $(63\times10^6 \, yrs.)$ after the big bang, i.e., 13.737 billion years ago (**TABLE 1**, **FIG.1**, $logR_{min} = 24.30$). The stars and galaxies already existed at this time [28].

Next, the present acceleration of expansion is compared with that in the future when the radius of the universe will be greater than it is at present:

For

$$\mathrm{R} = 4.4\times10^{26}\{m\}: \ \mathrm{A} = \frac{4E_r}{MR} - \frac{GM}{R^2} = 1.136\times10^{-8}\{\frac{m}{s^2}\} \quad \textit{(cf. eq. (20))} \tag{32}$$

For

$$R = 4.4\times10^{27}\{m\} \ : A \cong 1.14\times10^{-9} ms^{-2} \tag{33}$$

A comparison of equations (32) and (33) revealed that the universe will expand at a slower rate as its radius increases. This means that the universe consistently expands with acceleration, albeit at a decreasing rate. As the radius of the universe tends to infinity, the acceleration of expansion tends to zero.

R{m}	6.50×10^{23}	1.996×10^{24} **min**	3.99×10^{24}	4.40×10^{25}	4.40×10^{26}	4.40×10^{27}
Fc/m {N/m }	7.71×10^{-6}	2.51×10^{-6}	1.26×10^{-6}	1.14×10^{-7}	1.14×10^{-8}	1.14×10^{-9}
Fg/m {N/m}	2.37×10^{-5}	2.51×10^{-6}	6.28×10^{-7}	5.17×10^{-9}	5.17×10^{-11}	5.17×10^{-13}
log R	23.81	24.3 **min**	24.6	25.64	26.64	27.64
log Fc/m	-5.11	-5.60	-5.90	-6.94	-7.94	-8.94
log Fg/m	-4.63	-5.60	-6.20	-8.29	-10.29	-12.29

Table 1 **Coordinates of the points plotted in FIG.1 on a logarithmic scale.**

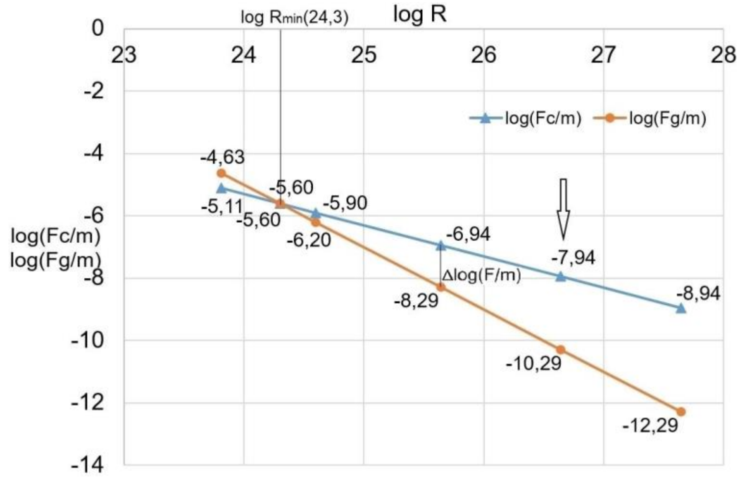

FIG. 1 **Dependence of the centrifugal force F_c and gravitational force F_g (divided by the mass of the selected body *m*) on the radius *R* of the universe on a logarithmic scale. The arrow in the diagram indicates the current radius of the universe. As the radius *R* increases, the gravitational force decreases faster than the centrifugal force. The difference between F_c and F_g is the net force (Δ*F*) that accelerates the expansion of the universe. The accelerating expansion started at R_{min} when the centrifugal force was equal to the gravitational force**.

Analysis of the acceleration equation *A*(*R*)

The acceleration equation A(R) is a square equation (26) that has an extremum:

$$\mathrm{A} = 4\frac{E_R}{MR} - \frac{GM}{R^2} = 4E_R M^{-1} R^{-1} - GMR^{-2} \qquad \textit{eq.(26)}$$

To calculate the extremum, equation (26) must be differentiated and then equated to 0:

$$f'(A) = 4EM^{-1}(-1)R^{-2} - GM(-2)R^{-3} = R^{-2}(-4EM^{-1} + 2GMR^{-1}) = 0 \qquad (34)$$

The roots of equation (34) are:

$$R_1 = 0 \qquad (35)$$

$$(-4E_R M^{-1} + 2GMR_2^{-1}) = 0$$

$$R_2 = \frac{2GM^2}{4E_R} = 3.9875 \times 10^{24}\, m$$

R_2 specifies the position of the maximum of A(*R*) **FIG. 2**:

$$A(\max) = A(R_2) = \frac{4E_R}{MR_2} - \frac{GM}{R_2^2} = 0.6281 \times 10^{-6}\, ms^{-2}$$

Where;

$E_R = 1.88 \times 10^{71}\, J$ -Kinetic energy of the rotating universe,

$G = 6.67 \times 10^{-11} Nm^2 kg^{-2}$ -Gravitational constant [15],

$M = 1.5 \times 10^{53} kg$ -Mass of the universe.

TABLE 2 lists a set of results of the function A(R) on linear and logarithmic scales.

FIG. 2 illustrates the temporal variation of the acceleration of expansion A due to the increase in the radius of the universe R due to expansion.

R{m}	1.99×10^{24} **min.**	2.5×10^{24}	3.9×10^{24}	9.0×10^{24}	4.4×10^{26}	4.4×10^{27}
A{m/s^2}	4.05×10^{-10}	4.05×10^{-7}	6.28×10^{-7} **max.**	4.34×10^{-7}	1.13×10^{-8}	1.14×10^{-9}
log R	24.3002 **min.**	24.3979	24.6011	24.9542	26.6435	27.6435
log A	-9.39	-6.39	-6.20 **max.**	-6.36	-7.95	-8.94

TABLE 2 **Coordinates of the points plotted in FIG. 2 on a logarithmic scale.**

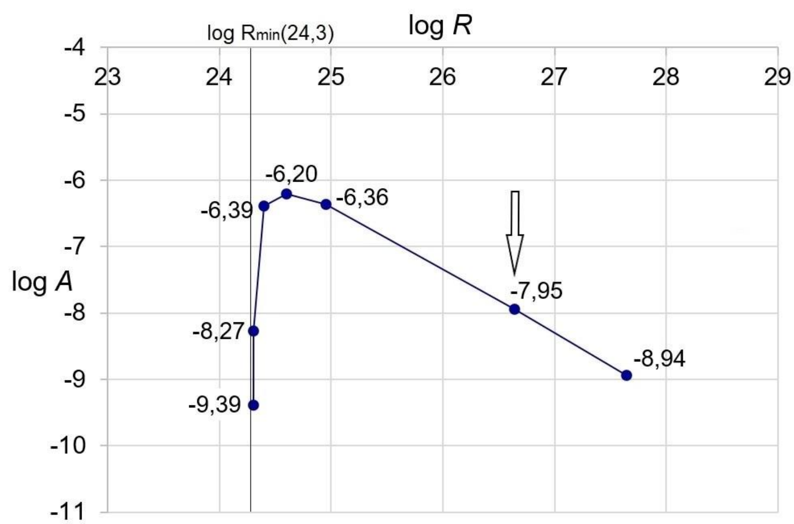

FIG. 2 **Graph of the function *A*(*R*) on a logarithmic scale, where: *A* - acceleration of the expansion of the universe, *R* - radius of the universe. The arrow in the diagram represents the current radius of the universe. As the radius of the universe increases beyond R_{min}, the acceleration of expansion surges to a maximum, and then begins to decrease more gradually.**

When the radius of the universe tends to infinity, the acceleration of expansion asymptotically tends to zero. In contrast, the speed of the universe's expansion at infinity tends to be a constant value. Currently, the acceleration of expansion of the universe is equal 1.13×10^{-8} m/s^2, and gradually decreases over time.

Discussion

• Compatibility of the angular velocity of the rotating Milky Way and the JD1 galaxy, during their formation, with that of the rotating universe is a strong argument for the rotation of the universe.

• The rotating universe is under the action of two immense forces: centrifugal force and gravitational force. The difference between these forces produces the resultant unbalanced centrifugal force that causes the expansion of the universe to accelerate.

• When the radius of the universe increases due to expansion, both the gravitational and centrifugal forces decrease. However, the gravitational force, which counteracts the expansion, decreases faster than the centrifugal force, causing the expansion to accelerate. Consequently, when the radius of the universe grows due to expansion, the centrifugal force is always greater than the gravitational force **FIG.1**. Therefore, the rotating universe is expanding at an accelerating rate. This conclusion implies that the source of the accelerating expansion of the universe is its rotation.

• The expansion rate began to accelerate when the centrifugal force equaled the gravitational force, i.e., when the radius of the universe was equal to R_{min}. This occurred approximately 63 million years after the big bang.

• In this study, dark energy is hypothesized to be the kinetic energy produced by the rotation of the universe (equation (6)). The results of calculating the rotation of the universe and its accelerating expansion justify the adoption of this hypothesis.

• The features of the kinetic energy of the rotating universe - constancy, permeation throughout the universe, opposition to gravitational force, and acting as the cause of the accelerating expansion of the universe - are the same as those attributed to dark energy by astronomers and cosmologists. However, the kinetic energy of a spinning universe provides a mathematically sound explanation for the accelerating expansion of the universe.

• The accelerating expansion of the universe causes the speed of the expansion continues to increase. However, the rate of this increase must continue to decelerate because, the acceleration of expansion decelerates as the radius of the universe increases, This relationship can be confirmed by astronomical observations, as experimental evidence for the rotation of the universe.

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Corresponding Author

Correspondence to Andrzej Szummer: aszummer@op.pl

Competing interests

The author declares no competing interests.

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