The structure of the Pivot universe

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The pivot theory presents a new approach regarding the structure of the universe. While originating from the dark matter theory, it claims that the dark matter resides within a black hole in the universe, the Pivot, rather than being spread out through the universe. Thus, supplying an answer as to why dark matter cannot be observed. The gravity force of the Pivot exists everywhere in the universe and influences all celestial bodies. The structure offered here is based on this hypothesis. The universe is composed of a spinning black hole, the Pivot, and a ring of a visible universe that is orbiting it. The Pivot theory explains, with high accuracy, known cosmological observations such as: The flattened rotation curve in spiral galaxies and the Spiral shape of galaxies.

These calculations are based on the primeval hadron theory, suggested by Muradian and others. The Pivot theory postulates that Kerr-Newman black hole is the object that connects between the very small primeval hadron and the entire universe.

Key words: Universe structure, Pivot, dark matter, angular momentum, hadron, high z shift

1. Introduction

The prevailing model for the evolution of the universe is the Big Bang theory. This model claims that the earliest state of the universe was extremely hot and dense and that it subsequently exploded and expanded. This expansion is expected to continue forever. Current cosmology, based on the Big Bang theory, faces several unresolved issues to name two, dark matter and dark energy. In addition, the Big Bang Theory has a problem of singularity indicating that the laws of physics cannot be applied at the moment of creation.

The Pivot theory uses an alternative theory. Muradian [1] and others suggest that the universe started as a super dense primeval hadron, size of a proton. His theory is based on the known experimental correlation between spin J, and mass M of particles like the hadron. He claims that such correlation exists also for all cosmic objects, starting from stars to clusters of galaxies. He shows that the computed values of J and M of celestial bodies are in good agreement with observations. However, when the mass of the universe is calculated by Muradian [2], based on the assumption that the hadron can be modeled as a **Kerr black hole**, the result is significantly lower than the accepted mass of the visible universe.

Oldershaw [3] and others suggests that the primeval hadron can be modeled as a spinning and charged **Kerr-Newman black hole (KNBH)**. Oldershaw theory is incorporated in the Pivot theory.

2. The Pivot theory

The Pivot theory is based on the Muradian [1] and Oldershaw [3] theories. According to quantum physics it is possible that the KNBH accumulated energy from the vacuum. As a result of accumulating the vacuum energy, the mass of the KNBH (M), its angular momentum (J) and its charge (Q) grew. Thus, the total mass of the hadron originated from two sources; the gravitational mass and the mass due to the electric charge Q. The KNBH growth continued until it reached an instability state and exploded. The reason for the explosion of the KNBH at the specific total mass and total angular momentum of the current universe, is still under research. For example, explosion of KNBH is described in the work by Hod [4].

The Pivot theory relies on two conservation laws: the mass conservation law and the total angular momentum conservation law. Based on the mass conservation law it is postulated that the total mass of the current universe is equal to the total mass of the hadron. According to the total angular momentum conservation law, the spin angular momentum of KNBH is equal to the sum of the spin angular momentum of the Pivot and the orbital angular momentum of the visible universe. The Pivot theory postulates that due to the fact that the KNBH had a spin, sub atomic particles tangentially flung off from it during the explosion. The tangential direction of the particles accounts for the ring shape of the current visible universe. The particles would have continued to move forever in their tangential direction but the explosion outwards of the hadron produced, according to Newton's 3rd law, an equal inward force. This resulted in particles moving towards the center. When the mass of the inward rushing particles was big enough, a new black hole, the Pivot, was created. A dynamic process occurred involving particles that quickly spread from the black hole and particles that were swallowed by the Pivot. Consequently, the Pivot grew bigger until it reached its current size. It should be noted that particles that were swallowed by the Pivot impinged it tangentially, causing it to rotate in the opposite direction to that of the particles that flew away from it. Eventually a state of dynamic equilibrium was reached. The particles that escaped the Pivot's event horizon started to orbit around it, creating the visible universe. Unlike the prevailing cosmology theory postulating that the dark matter is dispersed around the galaxies, the Pivot theory claims that the dark matter resides in the Pivot and therefore, most probably, will never be observed.

The Pivot theory explains the origin of spinning and rotation of celestial bodies. Since its creation, the visible universe orbited around the Pivot at a speed of ~0.7C (this velocity is calculated later). The temperature of the visible universe was very high and contained only a soup of sub atomic particles. Later on, 400,000 year after its creation the universe cooled down, ordinary atoms were created and this was the time that gravity forces between atoms appeared. The local density of the visible universe enabled several scenarios. If the density of atoms at a certain region in the visible universe was too low to enable attraction between them, they remained as a cloud of gas that orbits the Pivot. If the density of atoms was sufficient for interaction between them, then a nucleus of a star was created. The nucleus of the star encountered atoms from various orbits having different velocities which created a torque on the nucleus. Consequently, this nucleus began to spin. As the nucleus attracted more material it grew bigger and a spinning star, orbiting the Pivot, was born. If the mass of the star became big enough it collapsed and created a black hole. The black hole attracted other stars that started to orbit it. The stars orbiting the created black hole attracted additional stars and thus a full-size

galaxy was born. Assuming that the universe is rotating counter clockwise, all celestial objects spin clockwise.

Fig. 1 shows that the observable universe is contained within a sector of the visible universe ring. The sizes shown in the Figure are calculated later in my paper. The Milky Way radius is calculated to be 0.48Gly bigger than Rin. The Pivot theory explains an additional observation related to the handedness of the universe. Longo [5] found abundance of left-handed, or counter-clockwise rotating galaxies. The excess is small, about 7 percent, but the chance that it could be a cosmic accident is slim. Fig. 1 shows the equatorial plane of the visible universe and three galaxies, the Milky Way, and two arbitrary galaxies: Galaxy A and Galaxy B to explain the handedness of the universe. The Milky Way is located "above" Galaxy B and "below" Galaxy A. The Pivot theory predicts that all galaxies rotate in the same direction. The location of the galaxies in relation to the Milky Way will determine the direction of their rotation as seen from the Milky Way. Thus, Galaxy A will be seen as rotating clockwise (CW) when observed from the Milky Way, while Galaxy B will be seen as rotating counter clockwise (CCW) when observed from the Milky Way. Had the Milky Way been located on the equatorial plane then the number of CCW and CW galaxies would have been the same. However, if the Milky Way is located 7% under the equatorial plane than the number of CCW Galaxies is 7% in excess.

A Milky Way observer sees a big number of galaxies in whatever direction he looks. He may conclude that the entire universe is homogeneous. But for an observer in a galaxy located on the outer surface of the ring the universe is not homogenic. In one direction, he will be facing the vacuum which is totally dark and has a temperature of absolute zero. It should also be noted that also an observer that is located on the inner surface facing the Pivot, sees a total darkness and a temperature that is practically absolute zero. (The temperature of the Pivot is 1.5*10^-31K).

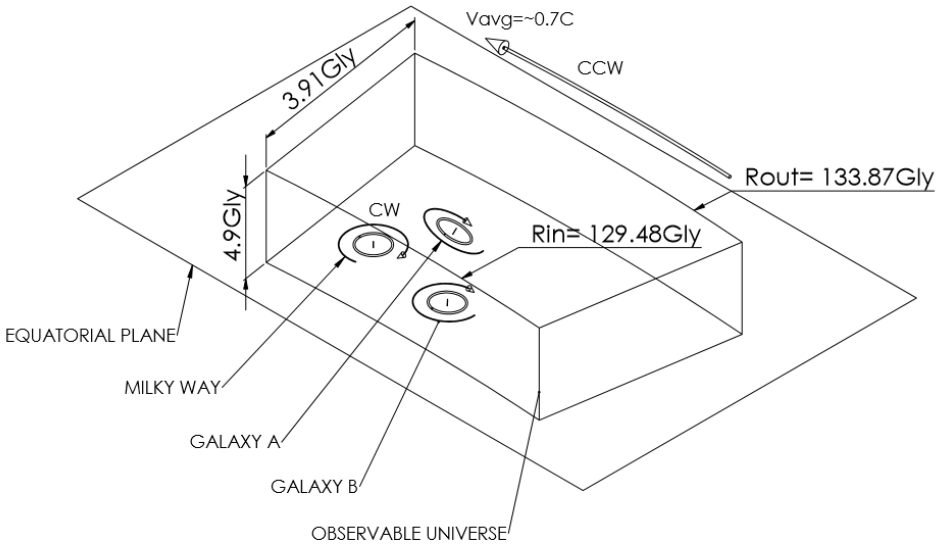

Fig. 1- The observable universe

3. Size of the universe

The following constants are used in the calculations for finding the size of the universe:

$Gly = 9.454 \cdot 10^{24}\,\mathrm{m}$ …Billion light years.

$G = 6.67 \cdot 10^{-11} m^3 / kg / \sec^2$ …Gravitational constant.

$C = 2.99 \cdot 10^8 m / \sec$ …Light velocity.

$\rho = 10^{-26} kg / m^3$ …Density of ordinary matter in universe.

$\hbar = 1.054571 \cdot 10^{-34} J \cdot \sec$ …Reduced Planck's constant.

$m_{proton} = 1.6726219 \cdot 10^{-27}\ kg$ …Mass of proton.

$\omega = 10^{-13} rad / yr$ …Angular velocity of the universe- Birch [6].

$M_{vu} = 1.5 \cdot 10^{53} kg$ …Mass of visible universe, Wikipedia [7].

$R = \dfrac{26.8\%}{4.9\%} = 5.47$ … Ratio of dark matter mass to visible universe mass, Wikipedia [8].

$M_p = R \cdot M_{vu} = 8.2 \cdot 10^{53} kg$ …Calculated mass of Pivot.

$M_{total} = M_p + M_{vu} = 9.7 \cdot 10^{53} kg$ …Calculated total mass of the universe.

The inner radius of universe ring must satisfy $R_{in} \geq$ Schwarzschild radius R_s:

$$R_{in} = R_s = \frac{2 \cdot G \cdot M_p}{C^2} = 129.48 \cdot Gly \qquad (1)$$

The conservation law of the total angular momentum states that the sum of the orbital angular momentum plus the intrinsic spin of a system is constant. The universe started as a hadron that had an intrinsic angular spin. As no other body existed, the universe orbital angular momentum was zero. Following the hadron explosion two distinct bodies were created: the Pivot, having only a spin angular momentum and the visible universe that has orbital angular momentum. Since the orbital angular momentum at the time of the hadron explosion was zero, the sum of the total angular momentum in the current universe must be also zero. It follows that the Pivot spin and the orbital angular momentum of the visible universe must be equal, albeit, with opposite signs. It should be noted that all celestial bodies i.e. stars, galaxies etc., also have spinning

angular momentum. However, it can be shown, that the sum of the spin angular momentum of all these celestial bodies is neglectable in comparison to the orbital angular momentum of the visible universe.

The spinning angular momentum of a disk like hadron (proton) is given by Muradian [1]:

$$J_{proton} = \hbar \cdot \left[\frac{M_{total}}{m_{proton}} \right]^{3/2} = 1.474 \cdot 10^{94} erg \cdot \sec \qquad (2)$$

The outer radius of the visible universe, R_{out}, can be calculated from (3). The left side of equation (3) is the angular momentum of the ring shaped visible universe. It is equal to half of the angular momentum of the proton:

$$\frac{M_{vu}}{2} \cdot (R_{in}^2 + R_{out}^2) \cdot \omega = \frac{J_{proton}}{2} \Rightarrow R_{out} = 133.87 Gly \qquad (3)$$

The width of the visible universe ring, W, can be calculated from equation (4):

$$M_{vu} = W \cdot \rho \cdot \pi \cdot (R_{out}^2 - R_{in}^2) \Rightarrow W = 4.9 Gly \qquad (4)$$

Fig. 2 shows the dimensions of the universe according to the above calculations.

The Pivot's spin ω_p can be calculated from equation (5). The left side of (5) is the angular momentum of the Pivot and is equal to half the angular momentum of the proton. It should be noted that the mass distribution inside a black hole is an open issue. In (5), it is assumed that the Pivot is a sphere with an equally distributed density. The minus sign indicates that the Pivot spins in opposite direction to the visible universe.

$$-\frac{2}{5} \cdot M_p \cdot R_s^2 \cdot \omega_p = \frac{J_{proton}}{2} \Rightarrow \omega_p = -4.73 \cdot 10^{-14} rad / yr \qquad (5)$$

The average velocity of the visible universe V_{avg} is calculated by equation (6):

$$V_{avg} = \left(\frac{G \cdot M_p}{(R_{in} + R_{out})/2} \right)^{0.5} \cong 0.7C \qquad (6)$$

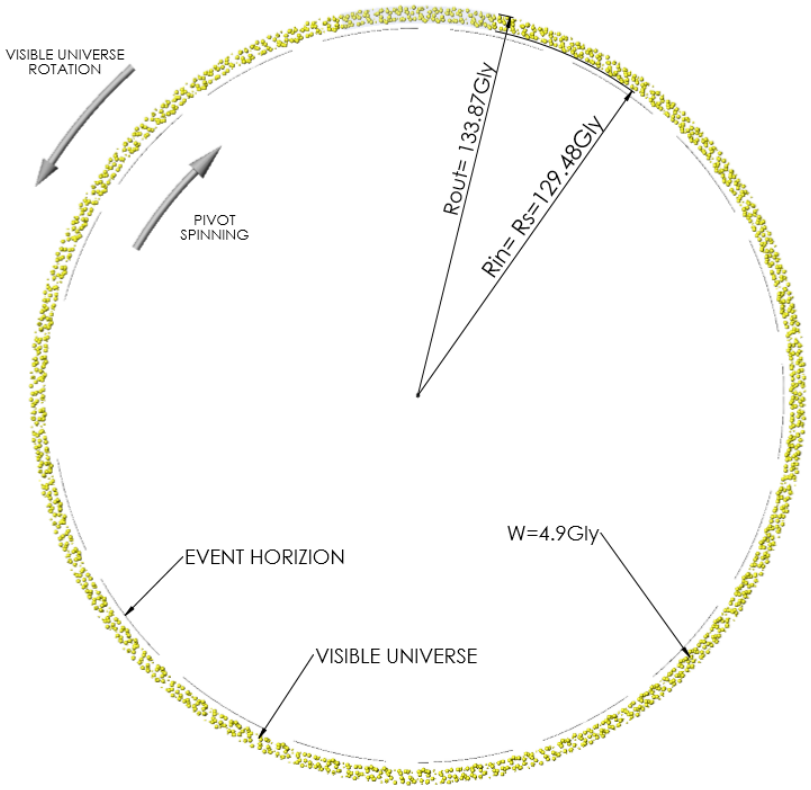

Fig. 2 – Dimensions of the universe

4. High z shift of galaxies

The Pivot theory claims that the z shift of galaxies is caused by the gravitational field, or Einstein shift, around the Pivot. This is contrary to the Big Bang theory which state that the z shift of galaxies can be explained by Hubble's law. Hubble's law indicates the existence of a linear relation between the receding velocity and the distance of a galaxy from Earth. This was found true for small redshifts but recent year research showed that for distant galaxies with high z galaxies this linear relation is not accurate and Hubble's graph curves upwards. Based on these observations, the Bing Bang theory concluded that the universe is expanding at an accelerated rate and that expansion is caused by a dark energy. Hubble's law is based on the Doppler effect which is caused by the relativistic velocity of the observed object. The Pivot claims that the z shift is dependent on the radius the galaxy orbiting the Pivot. Since the Pivot theory claims that galaxies are orbiting the Pivot at different velocities, the Doppler shift cannot be excluded, but its contribution is minimal and was calculated to be less than 0.2% (not shown in this paper).

Calculation of the gravitational wave shift of a galaxy Z_{gal_pivot} orbiting the Pivot at a radius R_{gal} , as seen from the Pivot, is given in equation (9) and also shown in Fig. 3 as the red curve:

$$Z_{gal\_pivot} = \frac{1}{\left(1 - \frac{2 \cdot G \cdot M_p}{R_{gal} \cdot C^2}\right)^{0.5}} - 1 \qquad (9)$$

Up to date, the highest galaxy z shift measured from Milky Way is $Z_{gal\_mw} = 11.09$ for galaxy GN-z11. The Pivot theory **assumes** that this galaxy is located at R_{out}. Then, from equation (9), the z shift of GN-z11, as seen from the Pivot, is 4.527. Thus, the z shift Z_{mw} of the Milky Way, as seen from the Pivot, can be calculated by equation (10). Note: Should future galaxies with higher z shift be found, Z_{mw} must be corrected accordingly.

$$Z_{mw} = 11.09 + 4.527 = 15.617 \qquad (10)$$

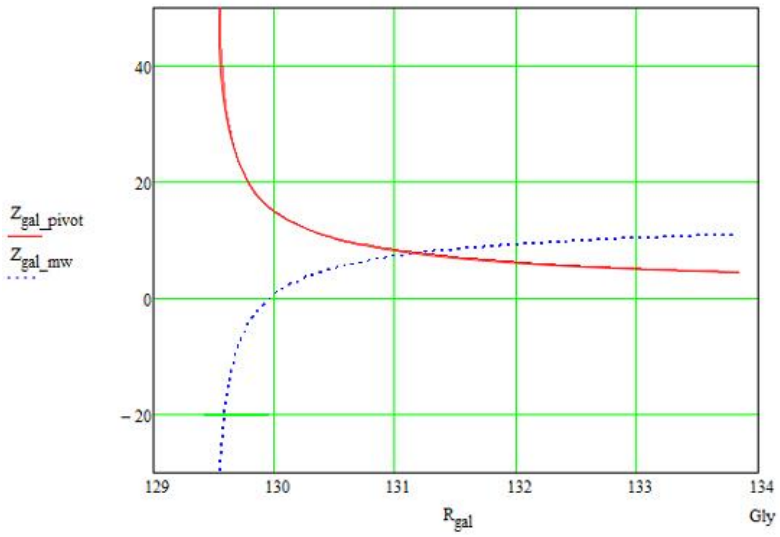

Fig. 3 – z shift of galaxies. a) Red curve – z shift of a galaxy as seen for the Pivot.

b) Dotted blue curve– z shift of a galaxy as seen from the Milky Way.

The z shift of any galaxy as seen from the Milky Way can be calculated by (11) and is shown in Fig. 3 as the dotted blue curve.

$$Z_{gal\_mw} = Z_{mw} - Z_{gal\_pivot} \qquad (11)$$

The z shift of the galaxy Z_{gal_mw} is a measured quantity as seen from the Milky Way. From (10) and (11) Z_{gal_pivot} can be found. Now, having Z_{gal_pivot}, the radius of any galaxy, R_{gal}, can be calculated using equation (9):

For the Milky Way $Z_{gal\_mw} = 0$, so $Z_{gal\_pivot} = Z_{mw}$ and the radius of Milky Way is $129.95814\,Gly$. Galaxies that are closer to the Pivot than the Milky Way, have a negative Z shift. For example, the measured blue shift of Andromeda is $Z_{gal\_mw} = -0.001001$ and the calculated radius of Andromeda is: $R_{gal} = 129.95808\,Gly$. A Milky Way observer will see that Andromeda is approaching him.

5. Rotation curve and spiral shape of a Galaxy

General:

In the following paragraph calculations are done for finding:

1. The rotation curve of a Galaxy as seen by a Milky Way observer.

2. The shape of a spiral Galaxy.

Note: The operators and functions used in this paragraph are in MathCad notations.

Given:

$G := 6.67 \cdot 10^{-11} \cdot \frac{m^3}{kg \cdot sec^2}$	Gravitational constant
$C := 2.99 \cdot 10^{8} \cdot \frac{m}{sec}$	Light velocity
$Kly := 9.4542 \cdot 10^{18} \cdot m$	Thousand light years
$Mly := 9.4542 \cdot 10^{21} \cdot m$	Millions light years
$Gly := 9.4542 \cdot 10^{24} \cdot m$	Billion light years
$R_{mw} := 129.96 \cdot Gly$	Radius Milky Way to Pivot (calculated earlier in this paper)
$M_P := 8.2 \cdot 10^{53} \cdot kg$	Mass of the Pivot (Calculated earlier in this paper)
$M_{bh} := 10^{36} kg$	Assumed Mass of Galaxy's Black Hole
$M_{gal} := 10^{39} kg$	Assumed Mass of Galaxy.

The rotation curve of a Galaxy as seen by a Milky Way observer:

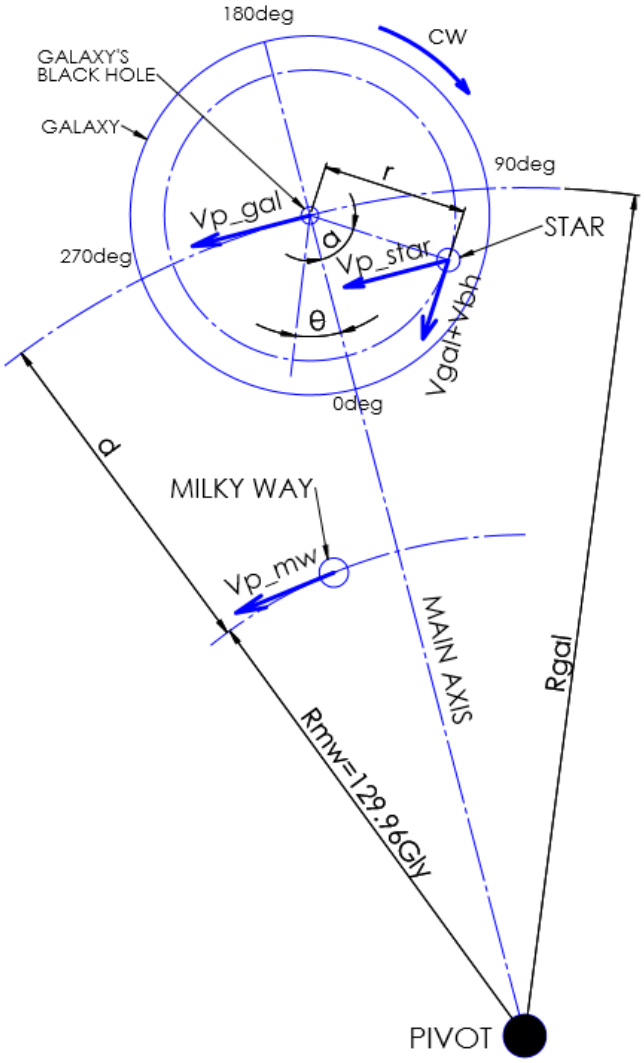

Fig. 4 – Velocities of a star

The gravitational forces exerted on a star in a spiral Galaxy are caused by:

a) Distributed mass of the Galaxy.

b) The Black Hole in the center of a Galaxy.

c) The Pivot.

Fig. 4 is used in the following calculations.

a) Velocity of a star due to distributed mass of the Galaxy

$r := 0.0001\,Kly, 0.01\cdot Kly .. 100\cdot Kly$ Distance range of star to its Galaxy center

$r_0 := 30\,Kly$ Assumed characteristic radius.

$$V_{gal}(r) := \begin{cases} \left(\frac{G\cdot M_{gal}}{r_0}\right)^{0.5}\cdot\frac{r}{r_0} & \text{if } 0\cdot Kly \le r < r_0 \\ \left(\frac{G\cdot M_{gal}}{r}\right)^{0.5} & \text{if } r \ge r_0 \end{cases}$$

Rotation velocity due to distributed mass of a Galaxy

b) Velocity of a star around the Galaxy's Black Hole:

$$V_{bh}(r) := \left(\frac{G\cdot M_{bh}}{r}\right)^{0.5}$$

c) Rotation velocity of a star in a galaxy orbiting the Pivot:

$d := 150\cdot Mly$ Arbitrary assumed distance

$R_{gal} := R_{mw} + d$

$$V_{p\_star}(r,\alpha) := \left(\frac{G\cdot M_p}{R_{gal} - r\cdot\cos(\alpha)}\right)^{0.5}$$

Summation of three velocities on the star:

$$V_{sum}(r,\alpha) := V_{p\_star}(r,\alpha) + \left(V_{gal}(r) + V_{bh}(r)\right)\cdot\cos(\alpha)$$

As a reference, the magnitude of the three velocities are compared for a star located 10Kly from the Galaxy's black hole. It is clear that the velocity of a star around the Pivot is dominant.

$$V_{p\_star}(10Kly, 0deg) = 210864 \cdot \frac{km}{s} \qquad V_{gal}(10Kly) = 5.1 \cdot \frac{km}{s} \qquad V_{bh}(10Kly) = 0.8 \cdot \frac{km}{s}$$

Orbital velocity of Milky Way around the Pivot:

$$V_{p\_mw} := \left(\frac{G \cdot M_P}{R_{mw}}\right)^{0.5}$$

Relativistic velocities:

The velocities of Galaxies in the universe, as shown earlier in this paper, are ~0.7C. Relativistic velocity of a star in a Galaxy as seen by a Milky Way observer is given by:

$$V_{star}(r, \alpha) := \frac{V_{p\_mw} - V_{sum}(r, \alpha)}{1 - \frac{V_{p\_mw} \cdot V_{sum}(r, \alpha)}{C^2}}$$

Summary regarding flattening of Galaxy curve

The rotation curve as observed for Galaxies is somewhat chaotic and is shown is shown in Fig. 5. The common characteristic for all observations is that as the distance of a star to the center of the its Galaxy increases the curve flattens out.

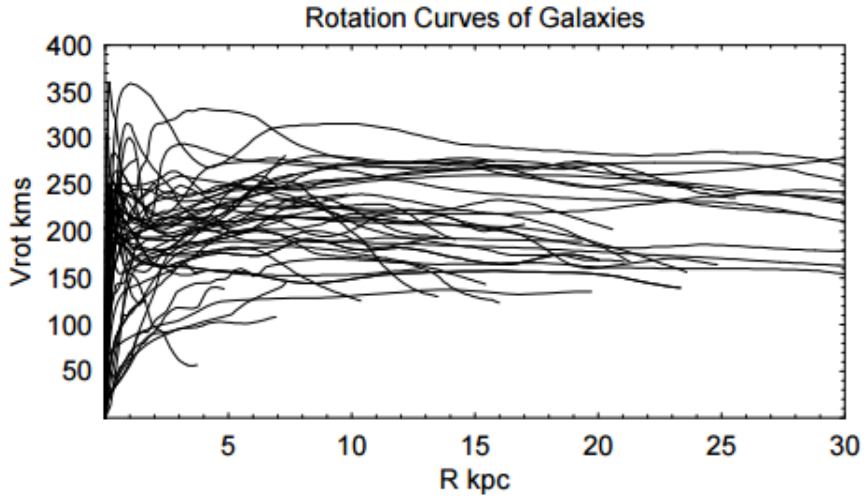

Fig. 5 -Rotation curves of Galaxies from: Sofue [9]

The prediction of the Pivot theory is that the observed velocities of stars in a Galaxy will be confined between the two extreme curves of the graph (solid red and dashed blue). The exact shape of the graph is dependent mainly on α, d and mass of galaxy.

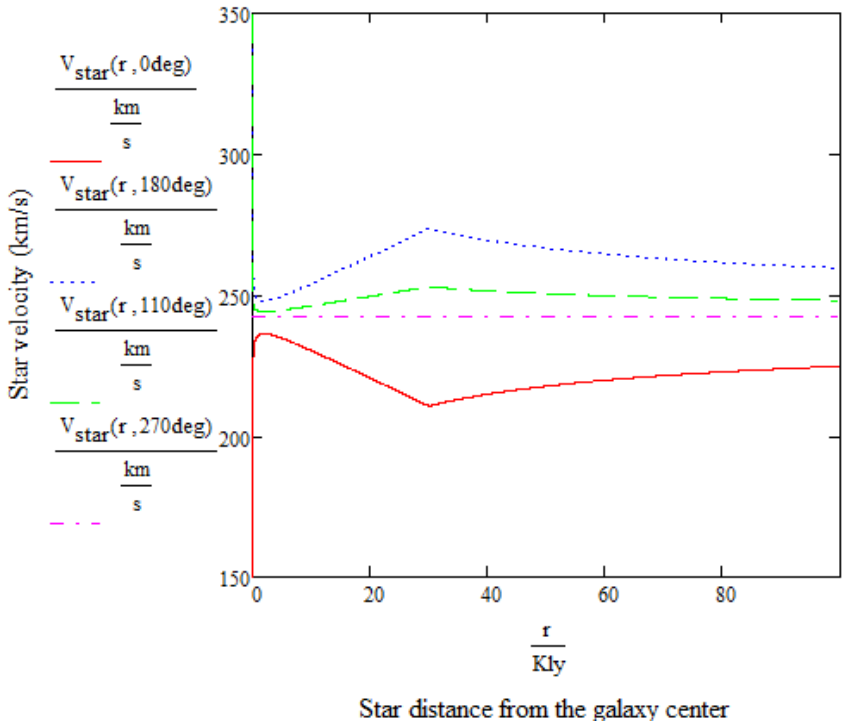

Fig. 6 – Rotation curve for a galaxy at a distance of 150 Mly from Milky Way

The shape of a spiral Galaxy

The angular displacement of a star orbiting the Galaxy's black hole (θ) is the integral $\int \frac{Vstar}{r} dt$. This integration is done only for stars that are on the main axis (the axis that connects the Pivot and the Galaxy's black hole, i.e., angles of 0deg and 180deg – (See Fig. 4). Only at these angles stars started to orbit around the Galaxy's black hole.

Fig. 6 shows the shape of a spiral shape galaxy 13.3 Billion years after the Galaxy creation. It can be shown that the spiral shape is changed at a very slow pace over Billions of years.

Note: The function mod of MathCad- returns the remainder on dividing x by y (x modulo y). In the current case y=360deg. The reason for using this function is that stars in galaxies have completed many full rotations around the Galaxy's black hole during 13.3 Billion years.

$$\theta_1(r,\alpha) := \mathrm{mod}\left[\left[\int_{0yr}^{13.3\cdot 10^9 yr} \frac{V_{star}[r,(\alpha)\cdot deg]}{r}\, dt\right]\cdot deg, 360deg\right]$$

$$\theta_2(r,\alpha) := \mathrm{mod}\left[\left[\int_{0yr}^{13.3\cdot 10^9 yr} \frac{V_{star}[r,(\alpha)\cdot deg]}{r}\, dt\right]\cdot deg, 360deg\right] + 180deg$$

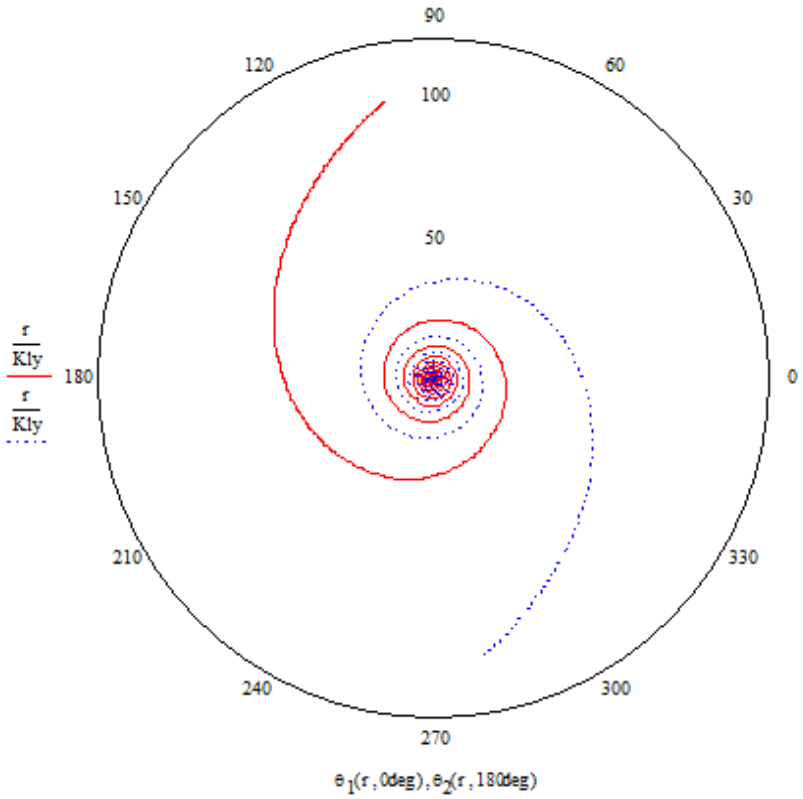

Fig. 6 – Shape of spiral galaxy 13.3 Billion years after its creation.

6. The hadron modeled as KNBH.

For calculating the mass of the universe, Muradian [2] assumes that the primeval hadron can be modeled as a Kerr black hole. He equates the maximal Kerr spin $J = \frac{G \cdot m^2}{C}$ to the angular momentum of the hadron $J = \hbar \cdot \left(\frac{m}{m_{proton}} \right)^{\frac{3}{2}}$. Muradian's calculations are in good agreement for celestial bodies. However, the result of this calculation gives the mass of the universe:

$$m = \frac{\hbar^2 \cdot C^2}{G^2 \cdot {m_{proton}}^3} = 4.77 \cdot 10^{49} kg \qquad (7).$$

The calculated mass from (7) is significantly smaller than the accepted total mass of the current universe $M_{total} = 9.7 \cdot 10^{53} kg$. This discrepancy can be resolved if the hadron is modeled as a KNBH, rather than a Kerr black hole. The mass of the KNBH is composed of gravitational mass and electrical charge mass. The mass of the universe calculated in equation (7) is the gravitational mass of the hadron and it is designated hereafter as M_g. The electric charge mass Q is a part of M_{total}.

Let assume $Q = \gamma \cdot M_{total}$, Than $M_{total} = M_g + \gamma \cdot M_{total} \Rightarrow \quad \gamma = 1 - \frac{M_g}{M_{total}} = 0.999\mathbf{51}$

KNBH must also satisfy equation (8)

$$Q^2 + a^2 \le {M_{total}}^2 \qquad (8)$$

The spin parameter a is defined: $a = \frac{J_{proton} \cdot C}{G \cdot M_{total}}$ and from (2) $J_{proton} = \hbar \cdot \left[\frac{M_{total}}{m_{proton}} \right]^{3/2}$

Substituting J_{proton} in a gives: $a^2 = \frac{\hbar^2 \cdot C^2}{G^2 \cdot {m_{proton}}^3} \cdot M_{total} = M_g \cdot M_{total}$

Further substituting Q and a^2 in equation (8) gives:

$\gamma^2 \cdot M_{total} + M_g \le M_{total}$ and finally, $\gamma \le \left(1 - \frac{M_g}{M_{total}} \right)^{0.5} = 0.999\mathbf{75}$

The value of γ shows that practically the entire mass of the hadron was contributed by electrical charge. It is still an open question why did the hadron exploded at this specific γ.

7. Results and discussion

The Pivot theory describes a universe which began as a hadron that can be modelled as a KNBH. It ended in the current universe composed of a spinning Kerr black hole, the Pivot, and a ring of visible universe orbiting the Pivot in an opposite direction to the Pivot's spin. The Pivot theory describes a universe that is in a state of dynamic equilibrium, indicating that the universe will exist forever. Everything in the visible universe may change, stars will consume their energy, galaxies orbiting at too close orbits will eventually collide etc. The Pivot will last forever; there is no other object in the universe that can threaten its existence. The Pivot theory explains in a simple way known cosmic observations, such as: Spin of celestial bodies, high z shift of galaxies, the flattened rotation curve in spiral Galaxies, Spiral shape of galaxies, etc. It addresses the issue of the dark matter and suggests that it resides in the Pivot and therefore, most probably, will never be observed. The dark energy theory is not required in this model.

Issues of the dynamic process that started with the primeval hadron and ended with the current universe are not fully addressed. The main issues is the mechanism that caused the hadron to explode when its mass reached the total mass of the current universe and how long it took the hadron to reach this mass.

Acknowledgment

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References

1. R. M. Muradian (1980) – "The primeval hadron: origin of stars, galaxies and astronomical universe" http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?bibcode=1980Ap%26SS..69..339M&db_key=AST&page_ind=0&plate_select=NO&data_type=GIF&type=SCREEN_GIF&classic=YES
2. R. M. Muradian (1987) - "The primeval hadron: origin of rotation and magnetic fields in the universe" http://adsabs.harvard.edu/full/1987IAUS..121..341M
3. R. L. Oldershaw (2006) - "Hadrons as Kerr-Newman Black Holes" https://arxiv.org/ftp/astro-ph/papers/0701/0701006.pdf
4. S. Hod (2016) – "Analytic treatment of the system of a Kerr-Newman black hole and a charged massive scalar field" https://arxiv.org/abs/1609.07146
5. M. J. Longo (2007) - "Evidence for a Preferred Handedness of Spiral Galaxies" https://arxiv.org/ftp/arxiv/papers/0707/0707.3793.pdf

6. P. Birch (1982) – “Is the universe rotating?” http://buildengineer.com/www.paulbirch.net/IsTheUniverseRotating.pdf
7. Wikipedia - https://en.wikipedia.org/wiki/Observable_universe#cite_ref-15
8. Wikipedia – https://en.wikipedia.org/wiki/Dark_matter
9. Y. Sofue (1999) – “Central Rotation Curves of Spiral Galaxies” arXiv:astro-ph/9905056