Using External Galactic Forces as an Alternative to Dark Matter

Scott S Neal[1]

October 4, 2016

I. ABSTRACT

It has been over 30 years since the first Cold Dark Matter (CDM) model was proposed as a way of describing Dark Matter, but as yet, there have been no experimental results that support CDM. CDM depends on the discovery of new non-baryonic particles not defined in the Standard Model as the source of the needed mass. Recently, final results from the Large Underground Xenon (LUX) dark matter experiment, have failed to find any traces of these non-baryonic particles, and the Large Hadron Collider (LHC) has not detected any strong evidence of supersymmetry particles. With the lack of supporting experimental results for CDM or supersymmetry, it is time to examine other solutions that might explain Dark Matter without requiring any new particles to be detected. The current concept of Dark Matter assumes the undiscovered particles add an additional gravitational mass to the galaxy. Another solution to the galaxy rotation problem would be to assume there is some external force pressing in on the galaxies holding them together. This research shows how external gravitational forces on the galaxies can duplicate the galaxy rotation curves that have been observed, without any Dark Matter. It also offers an explanation for the acceleration constant a_0, that results from the modified Newtonian dynamics (MOND) theory of galaxy dynamics. The results show that a model using an external galactic force is a valid approach to explain the effect known as Dark Matter.

Keywords—Antimatter, Dark Energy, Dark Matter, MOND, Rotation Curves

II. INTRODUCTION

NOW that the ALPHA experiment at CERN (M. Ahmadi, 2016) has created and captured antihydrogen atoms, the ALPHA team has begun the task of measuring the physical properties of neutral antimatter atoms. One measurement of great interest is the gravitational force exerted by antimatter atoms. While the current gravitational theories predict with some certainty (Noyes & Starson, 1991) that antimatter and matter will attract each other in all cases, the ALPHA team is attempting the difficult task of verifying the current theory. While the idea that antimatter exhibits an anti-gravitational force is not new (Lamb, 2007) (Neal, 2010) (Villata M. , 2012) (Nieto & Goldman, 1991), this paper uses that idea as a source for external forces on galaxies. This choice is made not to promote the idea of antigravity, but because gravitational equations and forces are well understood, and they do not require any major modifications to the Standard Model. To use antimatter as an external gravitational force on galaxies, it suggests that antimatter not only repels itself, but exerts a repulsive force on matter as well. This External Force Model also produces some surprising explanations of some unexplained astronomical observations that have been made (discussed later). If, within a few years, the ALPHA experiment disproves the existence of any anti-gravitational

[1] ScottNeal232@gmail.com

forces, the research in this paper still demonstrates how an external force on galaxies can simulate the effect called Dark Matter.

This research first must choose a model of how matter and antimatter interact gravitationally. There are several options that have been suggested, and the gravitational model for this research must be defined. Once a model has been defined, it must be applied to the evolution of the Universe to see how the existence of antihydrogen atoms expressing a repulsive force would affect the evolution of the Universe. The next step is to determine what resulting repulsive fields would exist today, and how they would affect the galaxies. With the combined attractive and repulsive gravitational fields producing a force on the stars in a galaxy, a rotation curve for that galaxy can be drawn and compared with astronomical observations. Finally, this research applies this External Force Model of Dark Matter to observations that are used to support the CDM model. This will test this External Force Model to see how it matches actual astronomical observations.

III. CHOOSING A GRAVITATIONAL FORCE EQUATION

To calculate rotation curves, a gravitational force equation that includes repulsive forces from antimatter is needed. There are four different possible models describing matter-antimatter gravitational interaction, each model describing how antimatter interacts with other antimatter, and how antimatter interacts with matter.

A. Antimatter Attracts Antimatter, Antimatter Attracts Matter – The conventional model states that antimatter exhibits the same attractive gravitational forces as matter (Noyes & Starson, 1991). Unfortunately, no antimatter stars or galaxies have ever been found, which leaves us with a missing antimatter problem that is being researched at this time.

B. Antimatter Attracts Antimatter, Antimatter Repels Matter – Another model that has been proposed is that antimatter attracts other antimatter, but the matter-antimatter interaction is repulsive (Ni, 2003) (Villata M. , 2011). While this still leaves us with the same missing antimatter problem, it does produce a repulsive force between matter and antimatter that could hold the galaxies together.

C. Antimatter Repels Antimatter, Antimatter Attracts Matter – A third possibility suggests that antimatter repels other antimatter, but the matter-antimatter interaction is still attractive. This model might be useful for this research if the antimatter is in the voids between galaxies and presses in on the galaxies. Unfortunately, this model doesn’t seem to have long-term stability since the matter is attracted to the antimatter where annihilation would occur.

D. Antimatter Repels Antimatter, Antimatter Repels Matter – The last possible model suggests a symmetry between the gravitational fields of matter and antimatter (Lamb, 2007) (Neal, 2010), and proposes that an ‘active’ mass of matter creates a gravitational field that will attract all ‘passive’ masses (matter and antimatter) placed in that field, while antimatter creates a gravitational field that will repel all masses (antimatter and matter). This model has a subtle difference from the previous model that was discussed in that the forces between matter and antimatter are both attractive (with the matter as the ‘active’ mass) and repulsive (with the antimatter as the ‘active’ mass) at the same time. Each ‘active’ mass in this model creates its own field, and the forces on a ‘passive’ mass in space are the summation of all of the active mass fields. The special issues that arise from just two equal masses with opposite forces will be discussed later in this paper.

This last model of antimatter gravitation (D) where antimatter repels all masses appears to be the best fit for the requirements needed for this research, and will be used.

Currently, Newton's gravitational equation describes only an attractive force from matter. There have some attempts to modify this equation for antimatter by suggesting that antimatter has a negative mass. If the concept of negative mass was used to describe antimatter, then two negative masses in Newton's gravitational equation would result in an attractive force for an antimatter/antimatter interaction instead of the repulsive force needed for this research. By not assigning a sign to mass, there is no challenge to Einstein's equivalence principal, and an antimatter feather and an antimatter hammer will be repelled from an antimatter Earth with the same acceleration. To meet the requirements for an external galactic force, a second version of Newton's gravitational equation is needed when antimatter is the active mass and is creating a repulsive gravitational field. If mass can't be negative, then the only solution would be to allow G, an empirical constant, to have a negative sign for an active mass of matter, and a positive sign for antimatter. Since the value of G is not tied to any other constant in nature, and its value is determined solely from measurement, there is no reason that it cannot have a different sign in a different experimental setup. With this definition of gravitational symmetry based on a signed G, Newton's law of gravitation for matter remains the same,

$$F_g = Any\ Mass_{passive} \left(\frac{-G\ * Matter\ Mass_{active}}{Distance\ to\ Matter^2} \right)$$

but for antimatter, becomes

$$F_g = Any\ Mass_{passive} \left(\frac{G\ * Antimatter\ Mass_{active}}{Distance\ to\ Antimatter^2} \right)$$

The equation for the total gravitational force on any passive mass m (matter or antimatter) from a system containing both matter masses and antimatter masses would become:

$$F_g = Any\ Mass_{passive} \left(\sum \frac{G\ * Antimatter\ Mass_{active}}{Distance\ to\ Antimatter^2} + \sum \frac{-G\ * Matter\ Mass_{active}}{Distance\ to\ Matter^2} \right)$$

These equations will be used to create new rotational curves for galaxies. The next step will be to see how antimatter exhibiting this repulsive force would manifest itself during the evolution of the universe.

IV. ADDING ANTIHYDROGEN TO THE CONCORDANCE MODEL

The currently accepted model of the Big Bang, the Concordance Model, asserts that there were equal amounts of matter and antimatter existing early in the evolution of our Universe (Canetti, Drewes, & Shaposhnikov, 2012). One problem unresolved in physics today is what happened to the antimatter, since the amount predicted by the Concordance Model has not been observed. There are two main proposals addressing the lack of observed antimatter. The most commonly accepted idea is that there was a time in the evolution of the Universe when the baryon number was not conserved, allowing matter to survive as is observed today (Dolgov, 2009) (Jones & Lambourne, 2004). The other idea is that somehow the surviving antimatter has formed into objects (e.g. stars and galaxies) which cannot be detected today (Dolgov, 2009) (Jones & Lambourne, 2004). This second idea predicts that antimatter atoms should clump together in a manner similar to that of matter. This research proposes a third solution that occurs naturally with repulsive forces between antimatter. If it is assumed that the baryon number has always been conserved, then after nucleosynthesis and recombination, equal amounts of neutral hydrogen and antihydrogen atoms would have existed. If matter warps space-time in a 'down' direction, then antimatter would warp space-time in an 'up' direction. With equal amounts of matter and antimatter, the Universe would be spatially flat. After recombination, the hydrogen atoms would begin to clump together following Newton's gravitational force equation. If, however, the antihydrogen atoms express a repulsive gravitational force on all other atoms, then no clumping of the antihydrogen atoms would occur. There would never be any antimatter suns or galaxies, and therefore no antimatter 'metals' would be created by fusion. The additional repulsive forces from the antimatter pushing on the matter, would accelerate the clumping of the matter into the large-scale web-like structure of matter observed today, while leaving large expanding clouds of antihydrogen atoms containing very little hydrogen (the voids). This might explain why today, only the voids seem to be expanding, and not the space inside of the galaxies. The additional external force from the voids, would cause the matter to collapse to form stars and galaxies at a faster rate than they would without any such external force. This external force might explain why some observations of the early galaxy development seem to indicate that the galaxies formed faster than current theories have predicted (Peebles & Nusser, 2010). Around each galaxy a balance would eventually be achieved where the constant expansion of the voids from the antimatter forces, would be balanced by the radiation pressure exerted by the fusion processes inside each galaxy, and any rotational forces existing in the galaxy.

The internal expansion forces of the antihydrogen in the voids might also help to explain the unexplained observation known as Dark Energy. As the universe evolves, the forces of the matter trying to hold the universe together would diminish as the distances increased, allowing the expansion forces in the voids to become dominant. This matches the observation made today that the speed of the universe's expansion is increasing.

V. DENSITY OF THE ANTIMATTER VOID

To determine the forces that the antihydrogen in the voids is applying on the galaxies, the current density of the antihydrogen in the voids has to be calculated. One approximation of this would be to assume that the current measured expansion rate of the Universe is produced by the expanding antihydrogen voids. Since the expansion rate of the Universe has been measured and is known as the Hubble constant, the amount of antimatter needed to produce the observed expansion rate can be calculated. To calculate the expansion rate due to the antimatter, a Gaussian spherical surface centered at an arbitrary point in an antimatter cloud is used. Using Gauss's law applied to gravity, the g-field at the surface of a sphere with a mass M, relative to the sphere's center is $g = GM/r^2$. To calculate the sphere's expansion from one side of the sphere to the opposite side, the acceleration is multiplied by 2: $g_{expansion} = 2GM/r^2$. Substituting $M = \rho(4/3\,\pi r^3)$ results in:

$$g_{expansion} = \frac{d^2r}{dt^2} = \frac{2G}{r^2}\frac{\rho 4\pi r^3}{3} = \frac{8\pi G\rho r}{3}$$

In the form of a differential equation:

$$\frac{d^2r}{dt^2} - \left(\frac{8\pi G\rho r}{3}\right)r = 0$$

Solving the differential equation for r and finding v/r will give an expansion rate of:

$$\frac{v}{r} = \sqrt{\frac{8\pi G\rho}{3}}$$

By setting the expansion rate of antimatter equal to the Hubble constant of $2.40\ x\ 10^{-18}\ s^{-1}$, the density of antimatter required to match the observed expansion rate of the Universe can be calculated as:

$$\rho = \frac{3H_0^2}{8\pi G} = 1.03\ x\ 10^{-26}\ kg\ m^{-3} \qquad (1)$$

This value is equivalent to approximately 6 anti-hydrogen atoms per cubic meter and would be difficult to detect while in a cold, unexcited state. If the antihydrogen has transformed into the molecular state with two antihydrogen atoms per molecule, this more stable state would make it even more difficult to detect.

VI. Repulsive Forces From the Voids

The antimatter force is assumed to follow the conventional gravitational inverse square law, but is directed in the opposite direction. As the voids grow in size, the antihydrogen clouds would become very large, nearly spherical, and uniformly filled with antihydrogen atoms. The force from such evenly distributed masses is zero at the sphere's center and increases linearly to the sphere's surface. Beyond the sphere's surface, the gravitational forces fall following an inverse square law relationship.

The voids in our Universe have been estimated to vary from 10 to 100 Mpc. in diameter (Plionis & Basilakos, 2002). A 40 Mpc void contains 9.85E+71 cubic meters of volume, and using the density derived in (1), has a mass of 1.01E+46 Kg. Since this mass is approximately 3 orders of magnitude larger than a large spiral galaxy, a 40 Mpc void at the edge of a galaxy will push any thinly distributed hydrogen atoms toward the galaxy. This push on the hydrogen clouds surrounding the galaxy would help the stars and galaxies form faster, and would clear the space between the galaxy and the void of any hydrogen atoms. There may be some evidence for this in observations that the density of hydrogen in spiral galaxies seems to have a relatively sharp edge when measured using 21 cm radiation. "The density of hydrogen drops away steadily ... and then drops dead over the last kiloparsec or so, and vanishes" (Freeman & McNamara, 2007).

Moving away from the void and closer to the galaxy, the magnitude of the repulsive force from the void will decrease, while the magnitude of the galaxy's attractive gravitational force will increase, eventually becoming the dominant component of the two forces.

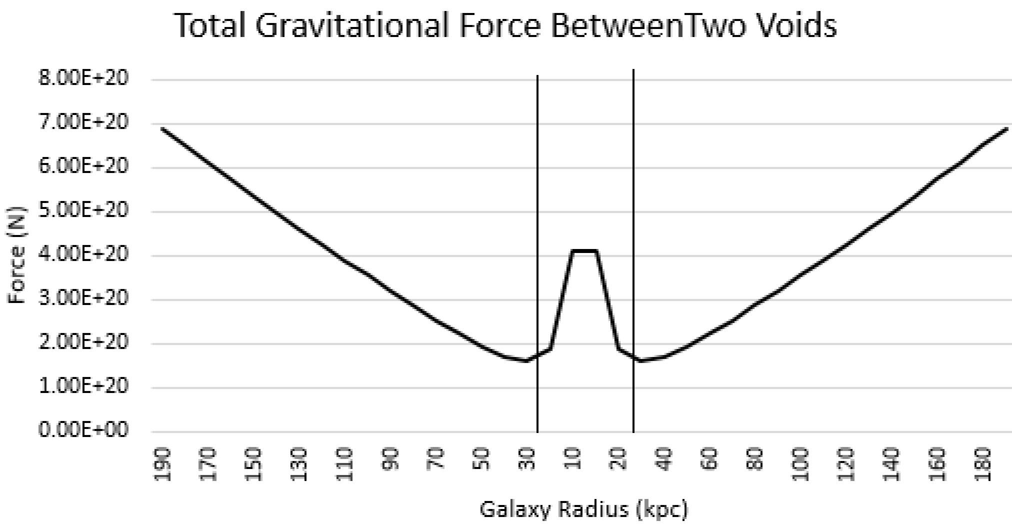

Fig. 1: The magnitude of the resulting gravitational force on 1 solar mass between the Milky Way and two voids (on either side). The direction of this resultant force is toward the galaxy center. At the far left and right of the graph, the external gravitational force from the galaxies will dominate, but slowly decrease following the inverse-square law. In the center of the graph the Milky Way gravitational forces dominate over the weaker forces from the void at that distance. The two vertical lines show the physical limits of the galaxy.

VII. Galaxy Escape Velocity

The force curve showing the magnitude of the inward gravitational force in Fig. 1, shows that the magnitude of the force decreases, as expected, as the distance from the center of the galaxy increases. At about 15 – 22 kpc from the center, the repulsive force from the voids becomes the dominant force, and at distances beyond that 'minimum force' point, the magnitude of the inward force on the Milky Way begins to steadily increase. By converting the standard equation for escape velocity using a central mass, to a form that uses the gravitational force on an orbiting star, a graph of the escape velocity from the galaxy can be obtained.

$$v_{escape} = \sqrt{\frac{2\ G\ M_{galaxy}}{r}} = \sqrt{\frac{2\ F_{gravity}\ r}{m_{solar\ mass}}}$$

The graph in fig. 2 shows how the escape velocity of stars orbiting the galaxy starts to increase at about 15 – 22 kpc from the center of the Milky Way, which would require more energy for stars to move farther away from the center of the galaxy. This critical distance happens to be at the point where it is estimated that the visible part of our galaxy ends.

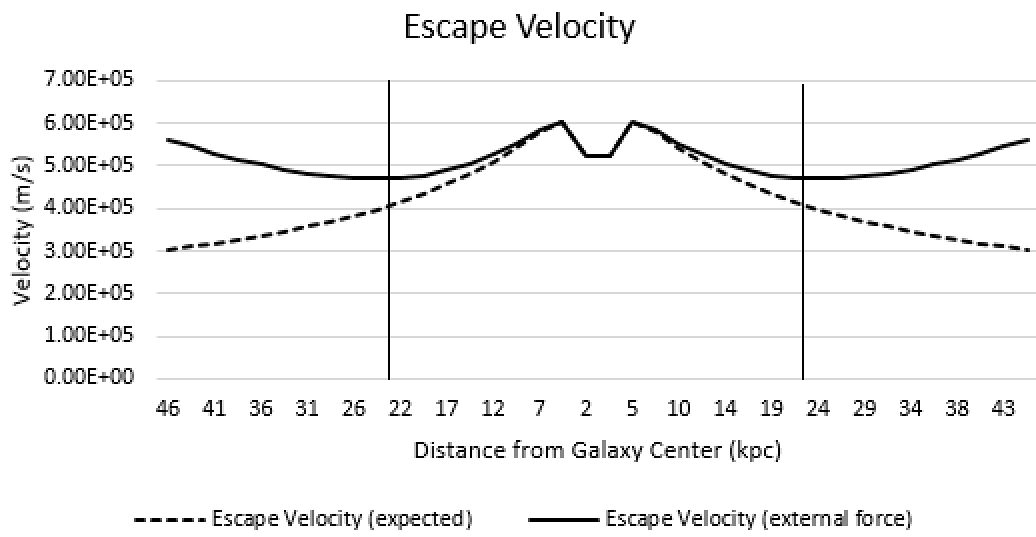

Fig. 2: The escape velocity of the Milky Way galaxy containing only conventional matter in proportion to its luminosity (expected) vs. the escape velocity which results when external forces are added. The two vertical lines show the physical limits of the galaxy.

If this data is correct, the possibility exists that the size (diameter) of a galaxy may depend on both the mass of a galaxy and the size of the voids near the galaxy.

VIII. Rotation Curves Using Antihydrogen

Traditional rotation curve equations only have parameters describing the force on an orbiting mass produced by a central mass inside the orbit of the orbiting mass. It is not the purpose of this section to develop a detailed rotational curve equation that includes both internal and external forces, but only to examine if by adding a new external force to the traditional equation, the results can approximate the rotation curves that have been observed by astronomers, without the need for any Dark Matter in the galaxies.

Conventional rotation curve equations use the gravitational force of conventional matter combined with a 'correct' amount of Dark Matter, to duplicate the observed rotational speeds on an orbiting mass. For this External Force Model, the rotation curve equation contains three forces on the orbiting mass. One force is from the conventional matter contained in the galaxy that attracts the orbiting mass towards the galaxy center, while a second force from the antimatter in the void nearest the orbiting mass pushes the orbiting mass towards the galaxy center, and a third minor force from the void on the ‘other side’ of the galaxy pushing the orbiting mass away from the center of the galaxy. These three forces will add to produce a single force on the orbiting mass. All three forces are calculated using the standard inverse square law of gravity originating from the galaxy’s central mass, or in the case of a void, from the outside edge of the spherical void.

$$F_g = M_{star} \left(\frac{-G * M_{galaxy}}{{r_{galaxy\ to\ star}}^2} \right) + \left(\frac{G * M_{near\ void}}{{r_{near\ void\ to\ star}}^2} \right) - \left(\frac{G * M_{far\ void}}{{r_{far\ void\ to\ star}}^2} \right)$$

In each galaxy composed of differing amounts of conventional matter and with different surrounding void sizes, this 'interplay' between the three forces will be unique and produce a unique rotation curve. It was predicted and has been observed, that in low surface brightness (LSB) galaxies, the ratio of Dark Matter to conventional matter is much higher than in large galaxies (Milgrom, 2015). The External Force Model explains this as the external forces being more dominant than the small internal forces of the LSB galaxy. In larger galaxies the conventional matter dominates to a larger distance from the galaxy center.

The graph of rotation curves in Fig. 3 was produced to show the results when the External Force Model is applied to the Milky Way galaxy. The curve labeled ‘expected’ was drawn using an exponential mass distribution algorithm which models what would be expected (Honma, et al., 2007) using conventional matter in proportion to its luminosity. The mass (dark plus conventional) used to model the Milky Way galaxy was 1.2 trillion solar masses with only 18% being conventional matter, and the radius of the galaxy used was 23 kpc.

It shows how without Dark Matter, the rotation curve decays with distance, as expected. The curve labeled ‘external force’ used the same forces found in the ‘expected’ graph, but added in the external forces from a void containing antihydrogen with a diameter of 40 Mpc, on each side of the galaxy. The forces from the void on the ‘other’ side of the galaxy will reduce the forces from the void on ‘this’ side of the galaxy because of opposite direction of the vector. As can be seen, the rotation curve flattens when the additional external forces are considered, without the need for any unknown particles of Dark Matter. The external force curve closely matches the actual rotation curve which has been created from observations (Honma, et al., 2007) (Sanders & McGaugh, 2002).

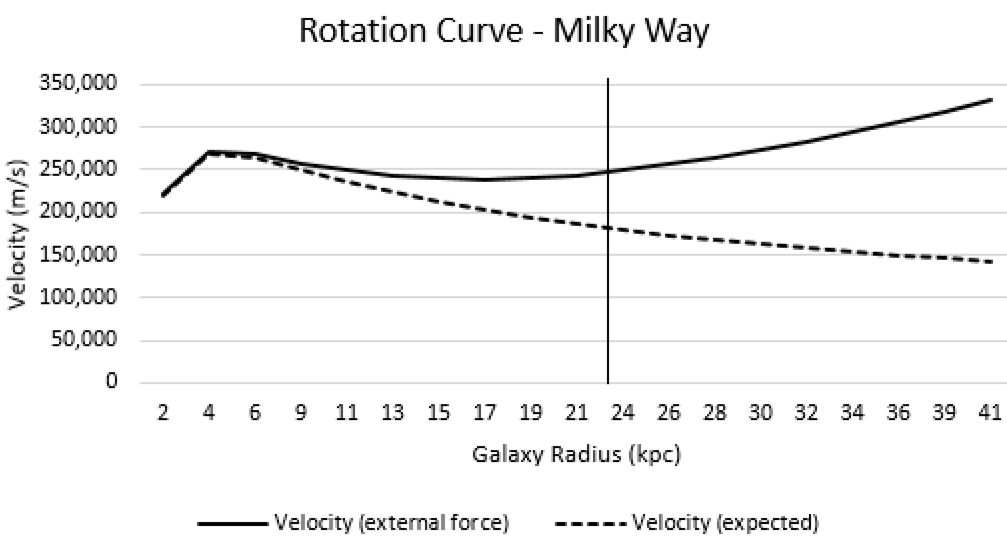

Fig. 3: The expected rotation curve of the Milky Way galaxy containing only conventional matter in proportion to its luminosity vs. the rotation curve which results when external forces are added. The vertical line indicates the edge of the galaxy used in the modeling. Note how that adding the external force can produce an almost flat rotation curve which is similar to what is observed.

As described previously, the rotation curves of LSB galaxies are very different from the larger galaxies. It has been theorized that this is due to Dark Matter dominating normal matter to a higher degree, but it is not known why this happens. Fig. 4 shows a graph of the rotation curves which were created to model these smaller galaxies. A value of 900 million solar masses was used for the mass of the galaxy, with only 5% being conventional matter, and a galaxy radius of 4 kpc was used. The value for the external force was the same as was used for the Milky Way. This simulation demonstrates how the domination of the external force causes the rotation curve to deviate significantly from the expected rotation curve for conventional matter alone. Again, the external forces curve closely matches the actual rotation curve which has been observed for galaxies of this size (Sanders & McGaugh, 2002).

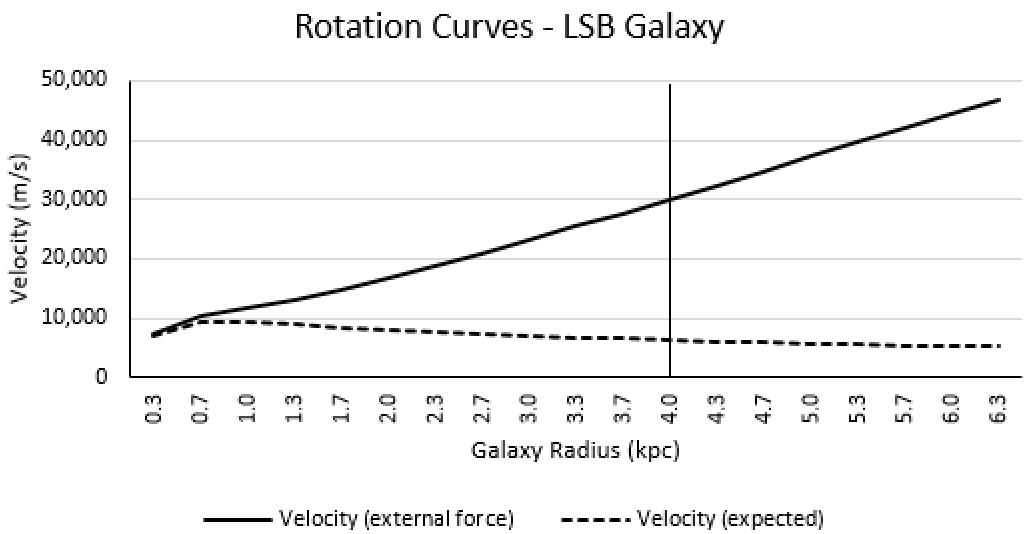

Fig. 4: Expected rotation curve of an LSB galaxy containing only conventional matter in proportion to its luminosity vs. the rotation curve which results when an external force is added. The vertical line indicates the edge of the galaxy used in the modeling. Note how adding the external force can produce a rotation curve which is similar to what is observed.

Most of the discussions of galaxy rotation curves describe how they are observed to be 'flat' at large distances. It should be pointed out that while the equations developed in this paper produce flat rotation curves inside the radius of our Milky Way, beyond the physical size of our galaxy, the velocity curve indicates greater velocities. Since there are no stars at this distance due to the increasing escape velocity, astronomers would not notice this increase. The velocity equations developed using external forces, show that at distances far from the galaxy, the velocity will increase in proportion to the square root of the distance from the galaxy center.

$$V \propto \sqrt{\frac{1}{r}}$$

IX. THE MOND VALUE OF a_0

Over 30 years ago, M. Milgrom suggested that a modification to Newton's laws could be a possible explanation for the discrepancies observed in the galaxy rotation curves (Milgrom, 2015). He showed that near a special value of acceleration a_0, a change in Newton's second law would describe the effects associated with Dark Matter. A review of the phenomenological success of MOND was done by Sanders & McGaugh (Sanders & McGaugh, 2002). In that paper they describe how by using the MOND approach, the Newtonian acceleration would have to be multiplied by an unspecified function $\mu(a/a_0)$. This function is described as having the asymptotic form:

$$\mu(a/a_0) = a/a_0 \ \textit{when} \ a/a_0 \ll 1$$
$$\mu(a/a_0) = 1 \ \textit{when} \ a/a_0 \gg 1$$

An external force offers a description for this modifying function. As described previously, in this External Force Model, there are three forces on each mass rotating in a galaxy, and therefore three separate sources of acceleration (from matter and from antimatter). The acceleration source from the voids becomes that function that modifies (adds to) the acceleration from the galaxy.

Near the center of a large size galaxy, the matter acceleration will dominate and then fall off at an inverse square rate with increasing distance from the center of the galaxy. At some distance from the galaxy center, the external force acceleration will become the dominant acceleration. This results in an acceleration curve for a galaxy which deviates from its expected Newtonian curve for a single central mass, by an amount of the external force acceleration component. The acceleration graphs in Fig. 5 for the Milky Way were plotted using the same masses which were used for the rotation curves discussed previously. As can be seen in the graphs, at the center of the galaxy, the external force acceleration is only about 6% of the total acceleration and doesn't provide much of an error to the expected acceleration curve. Moving away from the center, the external force acceleration becomes a much higher percentage of the total (observed) acceleration, becoming a full 76% of the total at the edge of the graph. It is interesting that the acceleration curve that uses an external force, flattens as it approaches the critical MOND level $a_0 = 1\ x\ 10^{-10}\ m\ s^{-2}$. This could explain why the MOND modification to Newton's laws matches so many of the astronomical observations (Sanders & McGaugh, 2002).

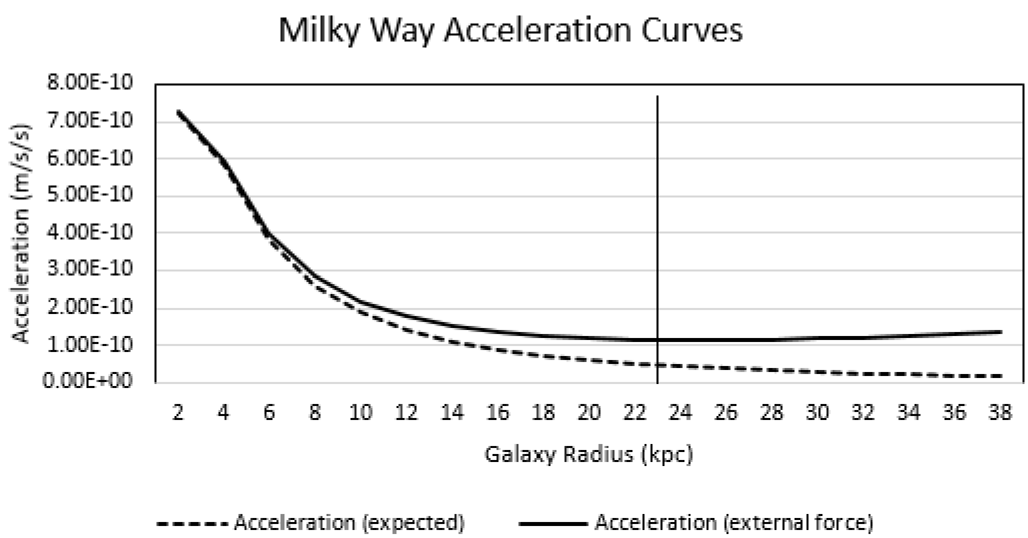

Fig. 5: Graph showing the acceleration which would be expected using only the traditional matter in the Milky Way galaxy (dashed line) compared to what would occur using an external force (solid line). It is used to show the significance of the MOND acceleration value of $1\ x\ 10^{-10}\ ms^{2}$. The vertical line indicates the edge of the galaxy used in the modeling.

X. Bullet Galaxy Cluster Collision

The collision of two galaxy clusters occurring in the Bullet Cluster (IE 0657-556) has been used as an example showing how Dark Matter does not interact with bosons or with other Dark Matter (Clowe, Randall, & Markevitch, 2007). The explanation given, is that as the two galaxy clusters passed through each other, the internal ionized gas within each of them was slowed by the drag force of the gas, while the galaxies in the clusters easily passed by each other. Today, the separate unaffected galaxy clusters are speeding away from each other with their ionized gas left behind, remaining between them. Since the mass of the ionized gas in a galaxy cluster is the largest percentage of the cluster's total mass, most of the mass resulting from the collision should remain in the ionized gas between the two galaxy clusters. A smaller percentage of the total mass should be left inside the clusters themselves. However, when measurements are taken, there appears to be significant matter inside the two galaxy clusters. This is explained as an effect from the Dark Matter associated with each galaxy not interacting with matter as the two clusters passed. In effect, the Dark Matter content of the two clusters passed right through each other just like the galaxies did and remained associated with the individual clusters.

With this External Force Model, there is no Dark Matter associated with each cluster. As the two clusters collided, the antimatter in the void between them was pushed out of the way by radiation pressures, creating one larger bubble containing both clusters. As the two clusters emerged after the collision they were once again surrounded by the antimatter, giving them the effect of having Dark Matter inside of them. In the future, if the clusters have enough velocity to keep moving away from each other, the antimatter will fill back in the void between them. If the ionized gas which collected between them does not get pulled back into either of the clusters, then it will eventually be enclosed in its own bubble in the cloud of antimatter.

XI. DARK FLOW

Dark flow is a term used to describe an observed non-random velocity of a group of galaxy clusters. Standard cosmological models indicate that the motion of galaxy clusters should be randomly distributed in all directions, with respect to the cosmic microwave background. However, astronomers have found evidence of a "surprisingly coherent" flow of clusters in a common direction (Kashlinsky, Atrio-Barandela, & Ebeling, 2011). It was noted earlier that cosmic voids range in size from 10 to 100 Mpc. If the magnitude of an external repulsive force is dependent on the size of the voids, then an unusually large void could be providing a large repulsive force on a group of galaxy clusters nearby, giving them a non-random velocity away from the void.

XII. ISSUES WITH ANTIMATTER FORCE MODEL

Since this External Force Model appears to match astronomical observations, the validity of the gravitational model that was used will now be examined. Suggesting that antimatter expresses a repulsive force, raises some serious questions about whether this model conforms to the known laws of physics. The biggest issue occurs when equal masses of matter and antimatter are placed in empty space and released. According to the force equations used in this model, the two masses would accelerate together as a gravitational dipole in the direction of the matter mass. This motion raises questions on whether the conservation of energy and momentum are being violated. The only way that this gravitational model can survive, is if the addition of antimatter to Newton’s and Einstein’s laws of motion allow such a motion.

XIII. ANTIMATTER FORCES AND THE ALPHA EXPERIMENT

As discussed earlier, there was one model that suggested that matter and antimatter always repel one another, while the model used for this research suggests that there are both attracting and repelling forces acting between them at the same time. With these dual forces, the motion of two masses of matter and antimatter will depend on which mass is bigger. The ALPHA experiment is currently measuring an antihydrogen atom to see if it falls toward Earth. If matter and antimatter always repel, then the antimatter atom should arise away from the Earth. Using the External Force Model with symmetrical gravitational forces, will show that the attractive force from the Earth on the antimatter atom is equal to the repulsive force from the atom on the Earth. But, because of the huge difference in masses, only the atom will appear to move in the direction toward the Earth. The Earth will be repelled away from the atom, but because of its huge mass, its motion will not be observed. Unfortunately, this result cannot be verified by the ALPHA experiment if they are only able to measure the motion of the antimatter atom toward the Earth.

XIV. CONCLUSION

The goal of this paper is to expand on an alternative to the current theories explaining Dark Matter. While most current theories of Dark Matter assert that the extra forces on a galaxy come from a sphere of Dark

Matter centered at the galaxy core, this model of Dark Matter suggests that the additional forces come from outside of the galaxy. The calculations in this paper show that an inverse-square external force can produce rotational curves and other effects attributed to Dark Matter. These other effects include the MOND a_0 constant, the high percentage of Dark Matter in LSB galaxies, the Dark Flow observation, and the weak interaction described in CDM particle theories. Most importantly, this External Force Model would explain why there have been no experimental results to back up existing Dark Matter theories dependent on undiscovered particles.

XV. References

Canetti, L., Drewes, M., & Shaposhnikov, M. (2012, September). Matter and Antimatter in the Universe. *New Journal of Physics, Volume 14*.

Clowe, D., Randall, S. W., & Markevitch, M. (2007). Catching a bullet: Direct Evidence for the Existence of Dark Matter. *Nuclear Physics Proceedings Supplements 173*, (pp. 28-31).

Dolgov, A. D. (2009). Baryogenesis and Cosmological Antimatter. *AIP Conference Proceedings 1116*, (pp. 155-170).

Freeman, K., & McNamara, G. (2007). In *In Search of Dark Matter* (p. 41). Praxis Publishing.

Honma, M., Bushimata, T., Choi, Y. K., Hirota, T., Imai, H., Iwadate, K., & et al. (2007). Astrometry of Galactic Star Forming Region Sharpless 269 with VERA : Parallax Measurements and Constraint on Outer Rotation Curve. *Oxford Journals->Publications of Astronomical Society of Japan, 59*, 889-895 fig. 4.

Jones, M. H., & Lambourne, R. J. (2004). In *An Introduction to Galaxies and Cosmology* (p. 361). Cambridge University Press.

Kashlinsky, A., Atrio-Barandela, F., & Ebeling, H. (2011). Measuring the Dark Flow with Public X-Ray Cluster Data. *The Astrophysical Journal, Volume 732, Number 1*.

Lamb, W. R. (2007, October). On Dark Energy from Antimatter. *SLAC-PUB-12849*, p. 11.

M. Ahmadi, M. B.-R. (2016). An Improved Limit On The Charge Of Antihydrogen From Stochastic Acceleration. *Nature 529*, pp. 373–376.

Milgrom, M. (2015). MOND Theory. *Canadian Journal of Physics, 93(2)*, 107.

Neal, S. S. (2010, January 9). *Antimatter in Voids Might Explain Dark Matter and Dark Energy*. Retrieved from viXra: http://rxiv.org/abs/1001.0007

Ni, G.-J. (2003, August 9). *A new insight into the negative-mass paradox of gravity and the accelerating universe.* Retrieved from arXiv:physics/0308038 [physics.gen-ph: https://arxiv.org/abs/physics/0308038

Nieto, M. M., & Goldman, T. (1991, July). The arguments against antigravity and the gravitational acceleration of antimatter. *Physics Reports, Volume 205, Issue 5*, pp. 221-281.

Noyes, P. H., & Starson, S. (1991, March). Discrete Antigravity. *SLAC-PUB-5429*, p. 16.

Peebles, P. J., & Nusser, A. (2010). Nearby Galaxies as Pointers to a Better Theory of Cosmic Evolution. *Nature 465*, pp. 565-569.

Plionis, M., & Basilakos, S. (2002). The Size and Shape of Local Voids. *Monthly Notices of the Royal Astronomical Society 330*, pp. 399-404.

Sanders, R. H., & McGaugh, S. S. (2002). Modified Newtonian Dynamics as an Alternative to Dark Matter. *Annual Review of Astronomy and Astrophysics, Vol. 40*, 263-317, figs. 3 and 5.

Villata, M. (2011, March 25). *CPT symmetry and antimatter gravity in general.* Retrieved from arXiv:1103.4937 [gr-qc]: https://arxiv.org/abs/1103.4937

Villata, M. (2012). Dark Energy in the Local Void. *Astrophys Space Sci*, p. 339. doi:10.1007/s10509-012-0994-9