Antimatter in Voids Might Explain Dark Matter and Dark Energy

Scott S Neal*

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Abstract

Traditional theories on cosmology require a sufficient amount of CP violation, undiscovered matter particles and missing energy to explain what is observed in our universe today. Traditional theories on antimatter assume that if antimatter atoms existed, they would distort space-time in the same way as normal matter. However, gravitational forces between antimatter atoms have not yet been experimentally measured. This paper speculates on what might happen if antimatter distorts space-time opposite to normal matter. The repulsive force of the anti-hydrogen atoms in the voids between galaxies would cause those voids to expand and would exert additional forces pressing inward on the galaxies. Simulations of this model produce galaxy rotation curves which match what is observed today without the need for any Dark Matter. An explanation of the MOND paradigm is also provided.

1 Introduction

The force of gravity produced by observed normal matter is not sufficient to explain the observed rate of galaxy formation, or the observed rotational speeds of galaxies and galaxy clusters [1]. In addition, normal visible matter does not seem to be the origin of the observed expansion of the universe [2]. These observations have been attributed to the theoretical existence of Dark Matter (holding the galaxies together) [1] and Dark Energy (causing the Universe to expand) [2]. The dominant theory for Dark Matter today, Cold Dark Matter (CDM), suggests that non-baryonic particles yet to be discovered are the substance of the Dark Matter. Unfortunately, CDM does not work well at galactic scales, so it suggests that in its current form, CDM still isn't a complete solution [3]. Vacuum Energy and Quintessence are two prominent theories for Dark Energy, but neither gives us a firm understanding of Dark Energy [2]. Limited empirical evidence exists as to the nature of the gravitational force between antimatter atoms [4]. This paper, expands on an idea proposed by Walter R Lamb[5] that is referred to in this paper as Antimatter In Voids (hereafter AIV). AIV speculates that if antimatter has a gravitational polarity which is the opposite of conventional matter, then vast tenuous clouds of anti-hydrogen atoms could exist in the voids between galaxies. The radiation and rotational forces in each galaxy will balance the antimatter forces pressing in on the galaxy and a stable 'bubble' will be established in the antimatter cloud. In the AIV model, the Universe is (in a spatial sense) one vast tenuous cloud of antimatter, with little bubbles of conventional matter forming galaxies spread throughout the cloud. This paper expands the original paper with examples and simulations that produce rotation curves which match what is observed without the need for the existence of Dark Matter.

2 Adding AIV To The Concordance Model

The most 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. One of the big mysteries in physics today is what happened to the antimatter, since the amount predicted by the model has not been observed. There are two main proposals of what happened to the 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, which allowed matter to survive as is observed today [6, 7, pg.361]. The other idea is that somehow the surviving antimatter has formed into objects (e.g. stars and galaxies) which cannot be detected today [6, 7, pg.361]. This second idea predicts that antimatter atoms should clump together in a manner similar to that of matter. The AIV model proposes that baryon number has always been conserved, and that after nucleosynthesis and recombination equal amounts of matter and antimatter atoms existed. With equal amounts of matter and antimatter, the Universe would be spatially flat. After recombination,

*8122 Louden Circle, Fort Collins, CO 80528,(email)ScottNeal32@comcast.net

the conventional matter atoms would begin to clump together under the gravitational force. If, however, the antimatter atoms express a repulsive gravitational force on each other, then no clumping of the antimatter would occur. There would never be any antimatter suns or galaxies, and therefore no antimatter 'metals' would be created by fusion. The forces from the antimatter would accelerate the growth of the structure of matter to create the large-scale structures observed today, while creating large voids where mostly antimatter atoms existed. 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 and the matter clumps and compresses to form galaxies, the forces on those galaxies from the antimatter cloud would shift away from an inverse square law relationship and shift towards a form which would reflect the extremely large volume of evenly distributed antimatter. This would be similar to the equations of infinite electrical charge distributions that result in a force which is constant in magnitude.

2.1 The Matter - Antimatter Gravitational Interaction

While the core assertion of AIV is that antimatter expresses a repulsive gravitational force when interacting on matter and other antimatter, there is still the issue of how matter interacts with antimatter. Whether matter attracts or repels antimatter, the AIV model will still work to explain Dark Matter and Dark Energy. Each of the two possibilities will now be explored.

2.1.1 Matter Attracts Antimatter

This possibility is a symmetric one, and the one the author supports. It states that antimatter repels both matter and antimatter, and matter attracts both matter and antimatter. On a cosmological scale, this possibility would cause antimatter to be attracted into the core of the galaxies, or any gravitational well. The conventional matter forming a galaxy's structure would stabilize based on the radiation pressure or rotational characteristics of the galaxy. But, at the same time, a thin cloud of antimatter would continue to flow toward the galaxy core, slowed only by the radiation pressure and other antimatter already inside the galaxy. At a density near 6 anti-hydrogen atoms per cubic meter at the outer regions of the galaxy (determined later in the paper), any annihilations between matter and antimatter might go unnoticed. But as the anti-hydrogen filters into the inner regions of the galaxy, the antimatter density would increase and annihilations would occur more frequently. Some evidence that might support this possibility that has been observed, is an unusual intensity of anti-protons and positrons detected by the PAMELA experiment[8].

The possibility of antimatter filtering inside of the galaxy has only a minor effect on AIV. The force from antimatter outside of a galaxy pushing matter toward the galaxy center would be many orders of magnitude larger than the force from antimatter inside the galaxy with its force acting in the opposite direction.

2.1.2 Matter Repels Antimatter

This possibility seems somewhat asymmetric, but is presented as another potentially valid possibility. It would state that matter attracts other matter, but repels antimatter, while antimatter repels both matter and antimatter. If matter repels antimatter, then their only interaction would require a large enough force to overcome their mutual gravitational repulsion, which would not be uncommon with gravity being the weakest force. Jets of matter being accelerated from the galaxy cores would be annihilated when contacting the surrounding antimatter cloud, generating gamma rays. At the edge of galaxies where the velocity of the atomic hydrogen is slow, a region of space would form that was empty of both matter and antimatter. 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."[9, pg.41] This seems like what would be expected if matter repels antimatter. A paper by Dragan Slavkov Hajdukovic[10] takes the possibility that matter repels antimatter and uses it to explain away the need for Dark Matter by the formation of virtual gravitational dipoles in the voids. The paper never addresses the forces between antimatter particles.

3 Expansion Rate of the Antimatter Cloud

Using the AIV model proposed in this paper, the voids containing clouds of mutually repelling anti-hydrogen atoms would cause the spaces between the galaxies to expand. To calculate the expansion rate due to the antimatter, a Gaussian spherical surface is centered at an arbitrary point in an antimatter cloud. Using Gauss's law applied to gravity, the g-field at the surface of a sphere relative to the sphere's center is $g = GM/r^2$. To calculate the acceleration from one side of the sphere to the opposite side, the acceleration is multiplied by 2: $g = 2GM/r^2$. Substituting $M = \rho(4/3\ \pi r^3)$ results in

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

In the form of a differential equation:

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

Solving the differential equation for r and finding v/r will gives 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 $2.40 \times 10^{-18}\ s^{-1}$, the density of antimatter required to match the observed expansion rate of the Universe can be calculated as

$$\rho = \frac{3H_0^2}{8\pi G} = 1.03 \times 10^{-26}\ kg\, m^{-3}.$$

This value equates to approximately 6 anti-hydrogen atoms per cubic meter and could contribute to, or be related to the effect known as Dark Energy.

4 Rotation Curves Using AIV

It will now be demonstrated how using the AIV model can produce the rotation curves which have been observed by astronomers. Conventional rotation curve equations use the gravitational force of conventional matter combined with a 'correct' amount of Dark Matter. For AIV, the rotation curve equation contains two forces on the orbiting mass, one from the conventional matter pulling the orbiting mass towards the galaxy center (F_g) and one from the force of the antimatter in the voids pushing the orbiting mass towards the galaxy center (F_{am}). These two forces are in the same direction and will add to produce a single force on the orbiting mass. F_g is described using the standard inverse square law of gravity. Since the antimatter is an extremely large cloud of evenly distributed anti-hydrogen atoms, F_{am} would take a form of a nearly constant force dependent on the density of the antimatter in the cloud. In the following simulations, the electrical force equation for an infinite distribution of charges was modified to produce a gravitational version, $F_{am} = 2\pi G\,\sigma_{eff}\,M_{orbiting}$. Moving away from the center of the galaxy, the force from conventional matter will decline following the inverse square law while the force from antimatter will remain somewhat constant. In each galaxy composed of differing amounts of conventional matter, this 'interplay' between the two forces will be unique and produce a unique rotation curve. It was predicted and has been observed [11], that in low surface brightness (LSB) galaxies, the ratio of Dark Matter to conventional matter is much higher than in large galaxies. The AIV model explains this as the antimatter forces becoming dominant closer to the galaxy center. In larger galaxies the conventional matter dominates to a larger distance from the galaxy center.

The equation used to plot velocity curves when a single force acts on an orbiting mass is, $v = \sqrt{F\,r/M_{orbiting}}$. Adding in the constant force from the antimatter, the equation becomes:

$$v = \sqrt{\frac{(F_g + F_{am})\ r}{M_{orbiting}}} = \sqrt{\frac{GM_{central}}{r} + 2\pi G\,\sigma_{eff}\,r} \tag{1}$$

The graph of rotation curves in Figure 1 was produced to show the results when the AIV model is applied to the Milky Way galaxy. The curve labeled 'Matter' was drawn using an exponential mass distribution algorithm which models what would be expected [12, fig.4] using conventional matter in proportion to its luminosity. The mass (dark plus conventional) used to model the galaxy was 3 trillion solar masses with only 9% being conventional matter and the radius used was 30 kpc. The velocity equation (Equation 1) derived above was used to plot the matter curve, with the F_{am} value set to zero. It shows how without Dark Matter, the rotation curve decays with distance. The curve labeled AIV used the same equation but added in a constant antimatter force. The value used for σ_{eff} ($\rho_{am} \times$ cloud depth) was varied to see if by using the AIV model, a rotation curve could be produced which matches the astronomical observations. As can be seen, the rotation curve flattens when the additional constant antimatter forces are considered, without the need for any unknown particles of Dark Matter. The AIV curve closely matches the actual rotation curve which has been created from observations [12, fig.4]. The value of σ_{eff} needed to match the observations would equate to an antimatter density of 6 anti-hydrogen atoms per cubic meter with a cloud thickness of 200 Mpc.

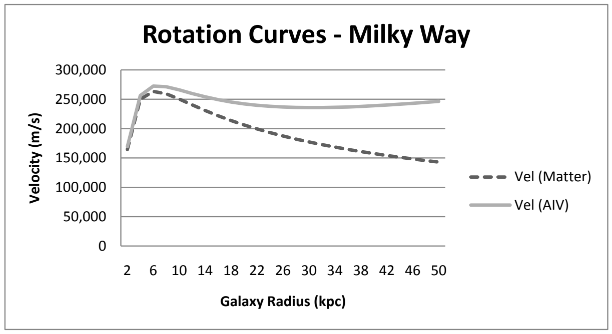

Figure 1: Rotation curve (dashed line) of the Milky Way galaxy containing only conventional matter in proportion to its luminosity vs. the rotation curve (solid line) which results when the force from antimatter is added. Note how that adding the antimatter force can produce an almost flat rotation curve 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. Figure 2 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 a radius of 4 kpc and a value for σ_{eff} being the same as was used for the Milky Way. This simulation demonstrates how the domination of the antimatter force causes the rotation curve to deviate significantly from the expected rotation curve for conventional matter alone. Again, the AIV curve closely matches the actual rotation curve which has been observed for galaxies of this size [13, fig.3].

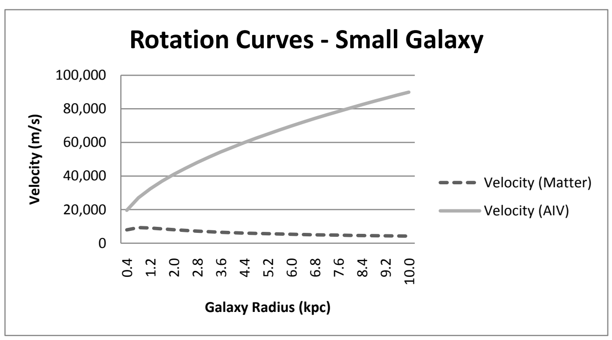

Figure 2: Rotation curve (dashed line) of an LSB galaxy containing only conventional matter in proportion to its luminosity vs. the rotation curve (solid line) which results when the force from antimatter is added. Note how that adding the antimatter force can produce a rotation curve which is similar 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 the equations developed in this paper do not produce flat rotation curves. While, for large galaxies, the AIV rotation curves produce a flattening which resembles the observed data, eventually the curve will predict higher velocities with greater distance. The velocity equation developed earlier (Equation 1), shows that at distances far from the galaxy, the velocity will increase in proportion to the square root of the distance from the galaxy center.

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

5 The MOND Value of a_0

Twenty five 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 [11]. 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 [13]. 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 $\mu(a/a_0) = a/a_0$ when $a/a_0 \ll 1$, and $\mu(a/a_0) = 1$ when $a/a_0 \gg 1$. AIV offers a description for this asymptotic function. As described previously, in the AIV model, there are two forces on each mass rotating in a galaxy, and therefore two separate sources of acceleration (from matter and from antimatter).

$$a_{total} = \frac{G\,M_{galaxy}}{r^2} + 2\pi G\,\sigma_{eff}$$

Near the center of a larger 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 constant antimatter acceleration will become the dominant acceleration. This results in an acceleration curve for a galaxy which deviates from its expected Newtonian curve by the constant antimatter acceleration value. The acceleration graphs in Figure 3 for the Milky Way were plotted using the same value for σ_{eff} which was used for the rotation curves discussed previously. Using this value of σ_{eff}, the acceleration due to the antimatter is a nearly constant value around $2.6\times10^{-11} m\,s^{-2}$. As can be seen in the graphs, at the center of the galaxy, the antimatter 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 antimatter acceleration becomes a much higher percentage of the total (observed) acceleration, becoming a full 70% of the total at the edges of the graph. It appears that the only significance of the value of a_0 $\left(1\times10^{-10} m\,s^{-2}\right)$ is that it is the point where the antimatter acceleration becomes a significant percentage of the total acceleration and thus the discrepancy starts becoming obvious.

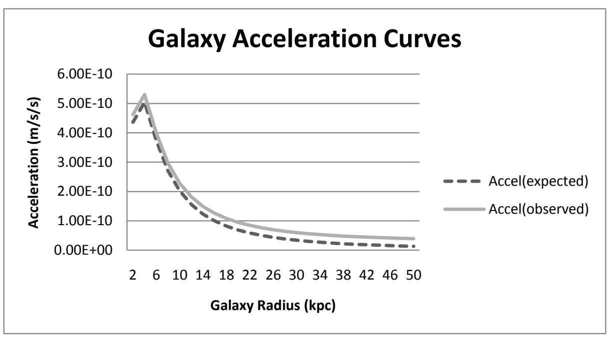

Figure 3: Graph showing the acceleration which would be expected using only the traditional matter in the Milky Way galaxy (dashed line) compared to what is actually observed (solid line). It is used to show the significance of the MOND acceleration value of $1\times10^{-10} m\,s^{-2}$.

6 Bullet Cluster Galaxy Collision

The collision of two galaxy clusters occurring in the Bullet Cluster (1E 0657-556) has been used as an example showing how Dark Matter does not interact with bosons or with other Dark Matter [14]. The explanation 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 in 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 regular 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 the AIV 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 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.

7 Proving AIV

There are two measurements which could be made to prove the validity of AIV.

1. The core assertion of this theory is that antimatter expresses a gravitational force which is opposite of conventional matter. Future anti-hydrogen experiments at CERN could prove or disprove AIV by measuring the force of gravity between antimatter [4]. It should be noted that the goal of the proposed experiments is only to measure the matter-antimatter gravitational forces.

2. If it was discovered that rotation curves are not truly flat, but that the velocity increases with the square root of the distance, this would add credibility to AIV.

8 Summary

The goal of this paper was to expand on an alternative to the current theories explaining Dark Matter and Dark Energy. 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 theory suggests that the forces come from outside of the galaxy. The calculations in this paper show that the density of antimatter needed to produce the effects attributed to Dark Matter and Dark Energy is of low enough density that it could have evaded detection up to this time. Whether or not the speculation in this paper about the forces of gravity from antimatter are true or not, it is interesting that modeling the galaxy rotation curves by adding an external constant force seem to match astronomical observations.

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