Early Galaxy Formation Modeled with Antihydrogen Atoms in Voids

Scott S Neal[1]

June 16, 2023

Abstract

With the launch of the James Webb Space Telescope (JWST), we are now able to make observations earlier into the history of galaxy formation for our Universe. Those observations have shown us that the current models of galaxy formation based on Dark Matter do not seem to be correct. Galaxies have formed much earlier than the current models would predict. These models use the conventional 'pulling' gravitational forces of both conventional matter and Dark Matter to predict how soon galaxies would form during the evolution of our Universe. This paper explores an alternative theory of Dark Matter to explain the earlier formation of our galaxies. This alternative theory suggests that antihydrogen atoms in the cosmic voids provide a 'pushing' force on all matter around them. This paper shows how, when the 'pulling' forces from matter and 'pushing' forces from antimatter are combined, they produce the more rapid formation of stars and galaxies.

Keywords – AIV, Antimatter, ASPIRE, CEERS, Dark Matter, Galaxy Formation, JWST, JD1, Voids

Introduction

The search for an explanation of the Dark Matter force has continued since it was first proposed by Fritz Zwicky in the 1930s. Although Dark Matter is just a concept used to explain galaxy rotational dynamics, theories have been suggested to describe the source of the Dark Matter force. These theories, mostly based on exotic ideas in Physics, have produced no direct observations of Dark Matter despite many decades of research effort.

New results from the JWST have shown mature galaxy formation between 500 and 700 million years into the evolution of our Universe. (Labbe, 2023) (Williams et al., 2023) The data comes from the Cosmic Evolution Early Release Science Survey (CEERS). (Boylan-Kolchin, 2023) These results conflict with current Dark Matter theories of galaxy formation based on the Lambda Cold Dark Matter Model that suggest mature galaxies should form around 2000 million years after the Big Bang. Something during the evolution of our Universe has caused galaxies to form at a much faster rate than expected. While the concept of Dark Matter must be included in the formation of galaxies, there are many different theories on the source of the Dark Matter force. This paper explores an alternative theory of the Dark Matter force (Neal, 2022) that proposes that antiatoms of hydrogen have collected in the Cosmic Web voids. These antiatoms express a gravitational

[1] Email: ScottNeal232@gmail.com

force that is of an opposite sign of the gravitational force of conventional matter. So, in essence, there are ‘pushing’ forces emanating from the voids that accelerate the formation of stars and galaxies. The goal of this paper is not to determine an exact timetable of when stars and galaxies would form, but just to investigate how a model using both a pulling and pushing force can cause a faster formation of stars and galaxies. Other ‘pushing’ forces, for example Dark Energy, could cause the same effect as described in this paper.

An Alternative Model of Dark Matter

Almost all the current models describing Dark Matter suggest that there are some undiscovered exotic particles (WIMPS, Axions, Primordial Black Holes) residing inside of the galaxies and along the web filament lines of the Cosmic Web. The gravitational pull of these exotic particles provides 85% of the observed gravitational forces in the Universe. The alternative Dark Matter model used in this paper, called Antihydrogen in Voids (AIV) (Neal, 2022), shows how the observed Dark Matter forces can be explained by forces originating from the Cosmic Voids pushing inward on the galaxies in the Cosmic Web filament lines. This second pushing force supplies an additional force needed to keep rotating galaxies stable. While the current Dark Matter models are based on exotic undiscovered particles, (Freeman & McNamara, 2007) this alternative model is based on an exotic undiscovered force of gravity. The one assertion made with this model is that while traditional hydrogen atoms express the traditional force of gravity on all other masses (both matter and antimatter), antihydrogen atoms express the opposite ‘pushing’ force on all other masses (both matter and antimatter). The AIV model assumes that the antigravitational force of antiatoms exists, much like research on WIMPs assumes that they exist when there is no proof to support that assertion.

The Evolution of the Universe with Antihydrogen Atoms

According to current theories (Gottfried & Weisskopf, 1984), matter and antimatter should have been created in equal amounts during the early formation of our Universe. Experiments with particle accelerators have proven that the theories of antimatter creation are correct, and those particle accelerators can create antimatter reliably. At CERN, experiments have been able to combine antimatter to form antihydrogen atoms. (CERN, What and Where is Antimatter, 2023) So we know, as a proven experimental fact, that hydrogen and antihydrogen atoms can be created and the current theories predict that they could have been created in equal amounts during the early evolution of our Universe. One problem with this theory is that no antimatter stars have been discovered. (CERN, The matter-antimatter asymmetry problem) If it is assumed that when the antihydrogen atoms were created and they exhibited a ‘pushing’ gravitational force on all other atoms, then they would never collect into antimatter stars. Instead, the antihydrogen atoms that were not annihilated by collisions with hydrogen atoms would collect in clouds of mutually repelling antihydrogen atoms while the hydrogen atoms would clump together under the forces of their own ‘pulling’ gravitational force. In addition to the ‘pulling’ forces bringing the hydrogen atoms together, the antihydrogen in the clouds would provide an additional ‘pushing’ force on those same hydrogen atoms. As a result, the atomic hydrogen and antihydrogen would form a structure very much like the Cosmic Web structure that we observe today, with voids of antihydrogen atoms, and web-like collections of hydrogen atoms along the edges of the voids. As the Universe in this model evolved, the pulling force of the hydrogen atoms would cause them to move sideways around the voids and condense into stars, galaxies, and galaxy clusters along the Cosmic Web filament lines while the cosmic voids would continue to grow and expand. The Webb telescope has observed this web-like structure after just 830 million years in the evolution of the Universe (Wang, 2023). Eventually, once fusion had begun in the matter along the web filament lines, radiation pressure would stop any further antihydrogen migration toward the stars and galaxies. The antihydrogen atoms in the voids today would be so tenuous as to make detection difficult, and hydrogen – antihydrogen annihilations producing detectible radiation would be rare. The voids would appear to be empty of any matter of any kind. A previous paper (Neal, 2022) shows how today, these forces from the external galactic voids would explain the effect called Dark Matter that is measured in galaxy rotation curves.

Attractive-Only Force vs Combined Attractive and Repulsive Forces

Most of the Dark Matter models assume that matter at the galactic scale consists of 15% traditional matter which we can see (Light Matter), and an 85% component of matter which emits no visible radiation (Dark Matter). These Dark Matter models assume that there are some undiscovered particles mixed within the Light Matter providing an additional gravitational attractive force. The result is one combined attractive force that varies with the inverse-square force of gravity. In the AIV model, there is no Dark Matter mass and therefore, no additional Dark Matter component of the attractive force. Only the Light Matter provides the attractive force and therefore, the attractive force from the galaxies is much less when there is no Dark Matter mass included. But, in a model that includes antihydrogen atoms providing a ‘pushing’ force from the voids, there are two forces acting on any Hydrogen atoms that are free to move and located between the galaxy and the void. To determine if the combination of the Light Matter pulling force and the Antihydrogen pushing force causes Light Matter to clump together faster than a Light Matter plus Dark Matter model pulling force, the size and amount of each type of mass needs to be estimated.

Difficulties in Modeling the Cosmic Web

The Cosmic Web has been modeled pictorially from computer simulations. Like any web it is mostly empty space with web-like filament strands of matter consisting of galaxy clusters, galaxies and hydrogen gas collecting around vast voids of empty space. The voids are approximately spherical in shape (Plionis & Basilakos, 2002) and today have radii from 5 to 62 Mpc. If a void is modelled as a sphere of antihydrogen, then a simple model of a point mass at the center of the sphere can be used. The web lines of matter are more difficult to model because the mass is not evenly distributed throughout the web filament lines. In some places the matter has clumped together as large galaxy clusters having masses from 10^{14} to 10^{15} solar masses, while in many other areas there is just hydrogen gas being slowly drawn into nearby galaxies. Since there is no clear standard relationship between the mass of any given void to the mass of the stars and galaxies at the edge of the void, this paper will calculate the forces between various mass configurations to see if any conclusions can be inferred.

Determining the Density of Antihydrogen in the Voids

Using the AIV model proposed in this paper, the voids containing clouds of mutually repelling antihydrogen atoms would cause the spaces between the galaxies to expand. It is assumed that the expansion rate of the Universe is tied to this expansion of the voids since observations indicate that only the voids are expanding. 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 result in an expansion rate of:

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

By setting the expansion rate of antihydrogen to the Hubble constant (H_0) of $2.40\ x\ 10^{-18}s^{-1}$, the density of antihydrogen required to match the observed expansion rate of the Universe can be calculated as:

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

This value equates to approximately 6 antihydrogen atoms per cubic meter, a very sparse collection of atoms. If the antihydrogen has formed diatomic molecules, these more stable molecules would be very difficult to detect.

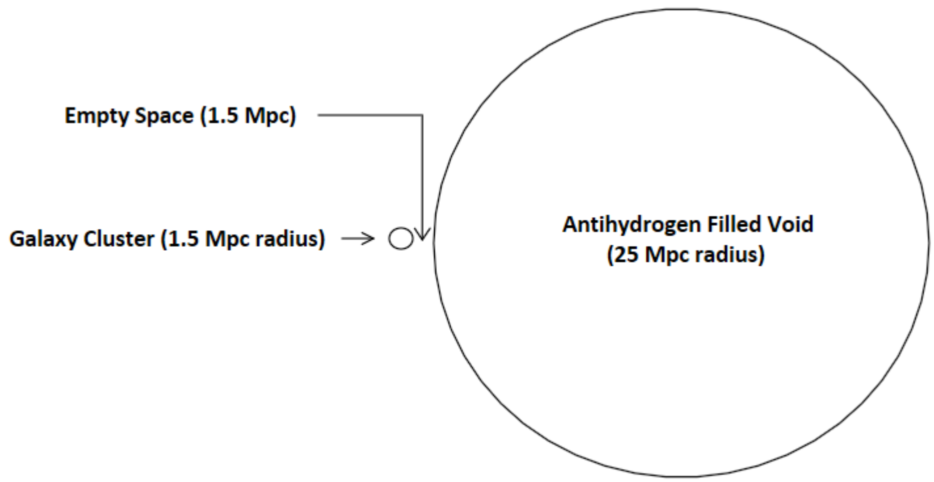
Calculating the Forces on the Test Mass

As discussed previously, it is almost impossible to model the Cosmic Web. At every point, the interaction between a void and a collection of regular matter is unique. So, as a starting point for this calculation, an average size galaxy cluster of 5E+14 solar masses (Kravtsov & Borgani, 2012) will be placed next to an average size void with a radius of 25 Mpc (Plionis & Basilakos, 2002), so that the forces on a test mass between them can be calculated for the Dark Matter model and the AIV model. Calculating a volume for a void with a radius of 25Mpc, and multiplying times the antihydrogen void density determined above, results in a mass of 1.98E+46 kg. For the mid-size galaxy cluster with a mass of 5E+14 solar masses, a result of a mass of 9.94E+44 kg is calculated. It is interesting to note that the galaxy cluster has only 5% of the mass of the void. This is an important point since the pulling force of the galaxy cluster using the Dark Matter model includes both Light Matter and Dark Matter masses, while with the AIV model the pulling force of the galaxy cluster uses only the Light Matter mass which is only 15% of the 'measured' Light Matter and Dark Matter mass. If the measured mass of the galaxy cluster was close to the mass of the void, then the Dark Matter model would provide a much larger pulling force than the AIV model's pushing force.

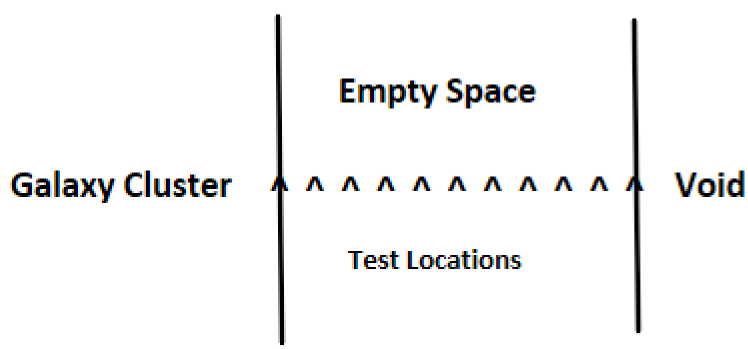
Now that the masses of the galaxy cluster and the antihydrogen void have been determined, the forces on a test mass placed between them can be calculated. If the void is assumed to be a sphere, then for gravitational force calculations, all the mass can be located at the center of the sphere. Since the size of the galactic cluster is many orders of magnitude smaller than the void, it too can be assumed to be a point mass at its center. Using these simplifications, the problem is now reduced to placing a test mass in the empty space between two point-masses and calculating the forces on the test mass produced by the two point-masses. For the Dark Matter model calculation, only the pulling force from the galaxy cluster (Light Matter and Dark Matter) is used, while for the AIV calculation, the pulling force of the Light Matter from the galaxy cluster is added to the pushing force from the antihydrogen in the void.

Calculating the Test Mass Motion for The Dark Matter Model and AIV

If this comparison was just between two central forces of different sizes from a common source, the solution would be obvious. The biggest central force would produce the fastest motion of the test particle. The calculation used in this paper for the AIV model is more complicated by the combining of two central forces emanating from two separate sources. As the test particle transitions toward the galaxy cluster the pulling force from the galaxy cluster increases while the pushing force from the void decreases at the same time. Closer to the void, the pushing force is the dominant force, while closer to the galaxy cluster, the pulling force dominates. To keep the analysis simple, the test mass is placed outside of the void and outside of the galaxy cluster. This assumes that the void and the galaxy cluster do not overlap and that there is an 'empty' space between them that has no matter or antimatter in it.



While this assumption simplifies the analysis and may not exist in reality, it will not invalidate the calculation which is trying to show the difference between a single central force and two central forces when acting on a test mass between them. The empty space will be divided into 10 equally spaced locations, and the test mass' movement will be determined at each location for a given increment of time. This is done to include any effects that the changes in the gravitational acceleration due to the two varying forces in the AIV model might have on the test mass movement.



The transition distance and time of the test mass as it moves through the empty space for the Dark Matter model and the AIV model can then be compared. If the AIV model causes the test mass to travel faster toward the galaxy cluster, then this might explain why galaxies are forming faster than the Dark Matter model would indicate.

The approach used to calculate the motion of the test mass is to first calculate the gravitational acceleration on the test mass at each location in the empty space for each of the two models.

$$Test\ Mass\ Acceleration_{Dark\ Matter\ Model} = \frac{G * ClusterMass_{Dark\ and\ Light}}{{Distance_{from\ cluster}}^2}$$

$$Test\ Mass\ Acceleration_{AIV\ Model} = \frac{G\ *\ ClusterMass_{Light}}{Distance_{from\ cluster}{}^2} + \frac{G\ *\ VoidMass_{antihydrogen}}{Distance_{from\ void}{}^2}$$

Once the acceleration is determined, and since the velocities involved are non-relativistic, the simple equation of motion can be used to calculate the distance traveled per unit of time.

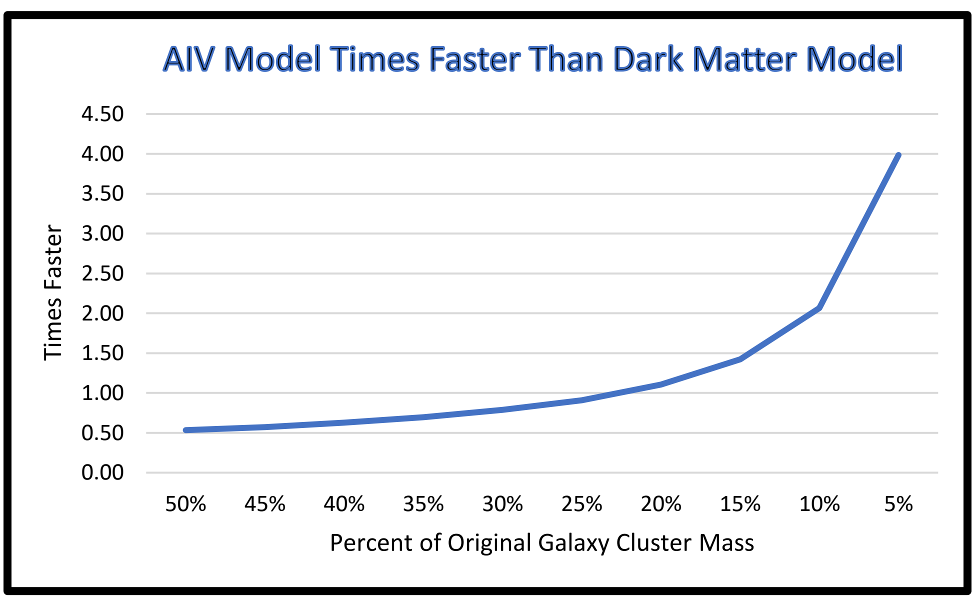
$$Distance = vt + \frac{1}{2}at^2$$

Adding up the distance traveled at each position will result in the total distance traveled by the test mass for each of the two models.

The results for a galaxy cluster with a mass of 9.94E+44 kg. and a void with a mass of 1.98E+46 kg. show that the Dark Matter model causes the test mass to travel farther than the AIV model. In the Universe today, around most of the large matter concentrations of galaxies and galaxy clusters, the Dark Matter model produces 3 times faster 'clumping' of matter into the web filament lines of the Cosmic Web than the AIV model.

Varying the Mass Concentrations at the Edge of the Void

The goal of this paper was to examine the galaxy formation time in the early phases of the evolution of the Universe. As described above in this paper, in the early formation of the Universe the degree of the 'clumping' of matter into larger masses was significantly less. Initially the matter around the voids was just simple hydrogen atoms spread evenly around the voids. In this situation, a test mass of a free hydrogen atom is more significantly impacted by the larger mass of the void than the distributed matter around the void. To model this situation, this paper reduces the mass of the galaxy cluster to see how it impacted the travel distance and time of the test mass. The following graph shows the results.



<u>Chart 1</u>: The bottom axis indicates what percentage of the original galaxy cluster's mass was used for the calculations. The vertical axis indicates how many times faster the AIV model was vs. the Dark Matter model in causing the 'clumping' needed to form stars and galaxies. A value less than 1 indicates that the Dark Matter model is faster, while a number greater than 1 indicates that the AIV model is that many times faster than the Dark Matter model.

When the matter at the edge of the void is less 'clumped', as it would in the early evolution of the Universe, the forces from the antihydrogen in the void become significantly larger than the 'pulling' force of the matter surrounding the void. This produces a significant non-linear increase in the travel distance of the test mass toward the existing Light Matter surrounding the void. This would cause an increase in the speed of galaxy formation as hydrogen gas is being swept out of the voids and accelerated into the already forming hydrogen clouds.

Summary

This paper has shown how a 2-force Dark Matter model containing both 'pulling' and 'pushing' forces produces a much faster galaxy formation time than a Dark Matter model containing only a 'pulling' force even with a much higher pulling mass. This result comes from the fact that in the early evolution of the Universe matter was not as 'clumped' together as it is today with the formation of galaxies and galaxy clusters. The result of the reduced clumping of Light Matter in the Universe allowed the forces originating from the voids to dominate the galaxy formation process.

Works Cited

Boylan-Kolchin, M. (2023). Stress testing ΛCDM with high-redshift galaxy candidates. *Nature Astronomy*. doi:10.1038/s41550-023-01937-7

CERN. (2023). *What and Where is Antimatter.* CERN. Retrieved from https://cms.cern/physics/what-and-where-antimatter#:~:text=For%20the%20past%2050%20years,obtaining%20the%20corresponding%20matter%20particles.

CERN. (n.d.). *The matter-antimatter asymmetry problem.* Retrieved from https://home.cern/science/physics/matter-antimatter-asymmetry-problem

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

Gottfried, K., & Weisskopf, V. (1984). *Concepts of Particle Physics. Vol. 1.* New York: Oxford University Press.

Labbe, e. a. (2023). A population of red candidate massive galaxies ~600 Myr after the Big Bang. *Nature*. doi:10.1038/s41586-023-05786-2

Neal, S. S. (2022). *Using External Galactic Forces as an Alternative to Dark Matter.* IntechOpen. doi:10.5772/intechopen.107163

Plionis, M., & Basilakos, S. (2002). The size and shape of local voids. *Monthly Notices of the Royal Astronomical Society*. doi:10.1046/j.1365-8711.2002.05069.x

Williams et al., 2. (2023). A magnified compact galaxy at redshift 9.51 with strong nebular emission lines. *Science*. doi:10.1126/science.adf5307

XENON, C. (2023). *First Dark Matter Search with Nuclear Recoils from the XENONnT Experiment.* Web Preprint. doi:10.48550/arXiv.2303.14729