The effects of superluminal Alcubierre drives and high velocity reference points on WIMP speed/energy

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Abstract

Within this study a particle with the parameters of the WIMP model of dark matter is analyzed in its interaction with a hypothetical Alcubierre drive. The Alcubierre drive has the seeming ability to violate the “speed limit” of light by utilizing a manipulation of Einstein’s equation to expand and contract space on either side of a given bubble to move it to different locations at arbitrary rates. The interaction of the drive with particles in space has been studied within literature, however, in this study the effects that the WIMP specifically has on the drives is determined in both its energy generation and gravitational accumulation. It is then compared to the effects of “light matter” particles. The data received from this topic is utilized to inspire a new model of WIMP average relative velocities. This model was devised by contrasting the velocities of particles interacting with the back to the front of a body in motion. The model displays a partially applicable function that is able to display a definable trend in the rate of average particle relative velocity growth as it relates to an increase in velocity of the body. Due to the fact the mass of the WIMP is constant, the energy of the particle is solely reliant upon its velocity, so a detection method is devised to determine the speed of dark matter and further prove the WIMP’s existence. This method is discussed.

1. Introduction

There are many theories that attempt to explain what the true essence of dark matter is. There is the axion, whose existence seems to solve for the "Strong-CP problem", and there is also the MACHO, which allows for a halo-based theory (1,2). There are some who even assert the idea that primordial black holes may be the answer for dark matter (3). Within this study, however, the particle based model of the WIMP will be analyzed. The WIMP, or weakly interacting massive particle, is a theoretical particle that acts through the weak force and gravity, and is believed to be super-symmetric with mass and abundance in just the correct ratio to be accountable for the physics issues that require the existence of dark matter. The WIMP is assumed to have about 10 GeV resting mass. On average there are assumed to be approximately 10 WIMPs per cubic centimeter.

The fundamental speed limit for all observers within the universe is the speed of light, yet Miguel Alcubierre has theorized a metric which allows for a seeming violation of such a rule (4). Despite how it may seem to an outside observer, the speed of light condition is not technically violated, as the method of the Alcubierre drive's travel is the warping of space time in the front and back of a bubble that moves the bubble forward in a time-like freefall. This is therefore more similar to the expansion of the universe rather than the propulsion of a rocket (5). Alcubierre was able to conceive such a metric through the manipulation of Einstein's general relativity equation:

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \tag{1}$$

$T_{\mu\nu}$ stands for the energy momentum tensor, while $G_{\mu\nu}$ stands for the Einstein tensor. G stands for Newton's gravitational constant and *c* is the speed of light. Instead of being given mass and solving for the contractions because of it, Alcubierre instead defined a field that gave him the desired effect of FTL (faster than light) travel, then solved for the mass required to achieve it, revealing the equation below:

$$ds^2 = -dt^2 + (dx - v_s(t)f(r_s)dt)^2 + dy^2 + dz^2 \tag{2}$$

V_s stands for the velocity of the ship within the drive while $f(r_s)$ is a function to define the shape of the drive. The remaining symbols stand for the temporal and spatial dimensions of space-time. The Alcubierre drive is, regrettably, currently only an equation and not a feasible structure. Many issues do exist that conflict with its creation in the physical world. One such problem is the fact that exotic matter is required (6). There needs to be some amount of negative energy in order to bend space-time in such a way, yet no such matter has yet been discovered.

An issue examined within this study is that of what happens when particles found within space interact with the extremely fast drives and their warps in space-time (7). This causes the particles to become time-locked for the duration of the journey until they are released with the deceleration of the drives as they reach their targeted destination. The large amount of energy that is received from these released particles is enough to cause mass damage to much matter found within the target destination.

Although the literature covered a wide range of particles that may interact with superuminal and subluminal drives, including both null and massive particles, this study attempts to gain a better understanding of how the specific WIMP model of dark matter interacts with these drives.

Although the Alcubierre drive is certainly an interesting concept, as previously stated, it is merely a theoretical invention at this point. That is why this study then uses concepts derived from its analysis of dark matter's interaction with Alcubierre drives in order to better understand the concept of WIMP speed and energy, and devise hypothetical detection methods in which they are able to be better defined. This is done through the determination of the average relative velocity of dark matter particles as they interact with a body in space not only from its front, but also its back. A function is created to explain the average relative velocity of WIMPs as they interact with a body in motion. This function poses a potential challenge to the idea that the speed of dark matter when compared to the Earth is approximately 220 km/s, as was assumed to be true due to the solar system's orbit around the galactic center being traveled at that speed (8). If Earth's velocity compared to the galactic center is lower than the maximum speed of a WIMP Particle, the average speed of dark matter as it interacts with the Earth may vary dramatically from that point.

This function is also used to conceptualize a detection method of Dark Matter based on the DAMA/LIBRA detector in Italy that utilized sodium iodine as a crystal structure that produces scintillations, or flashes, when a particle interacts with one of its nuclei (9). Previously the quantity of scintillations has been utilized as a method to determine the existence of dark matter, where during the months when Earth moves with the sun the scintillation quantity increases, whereas when it moves against the sun it decreases. If the rate at which photons were produced from scintillations as the Earth increased in velocity was used instead it would not only provide a new detection method for dark matter solely reliant upon energy fluctuations, but also an estimate on the speed of WIMPs (10).

2. Alcubierre Drives

2.1 Particle Speed

The speed of a theoretical WIMP particle is not known precisely, however it must be moving non-relativistically in order to behave as it does. This is because the particles must be moving "slowly" in order to form halos around ordinary matter rather than being strewn across the universe (11). For the sake of this part of the study we will assume a maximum WIMP speed of 300 km/s. This is slow enough to act as a source of dark matter, yet still fast enough to act as a particle. This postulated speed is equivalent to approximately 0.001c (0.1% the speed of light). The speed of the Alcubierre drive is arbitrary, and can be made to be both superluminal (faster than the speed of light) and subluminal (slower than the speed of light). Regions have already been constructed within the literature to define interactions with particles and drives at given speeds, and can be observed in Figure 1.

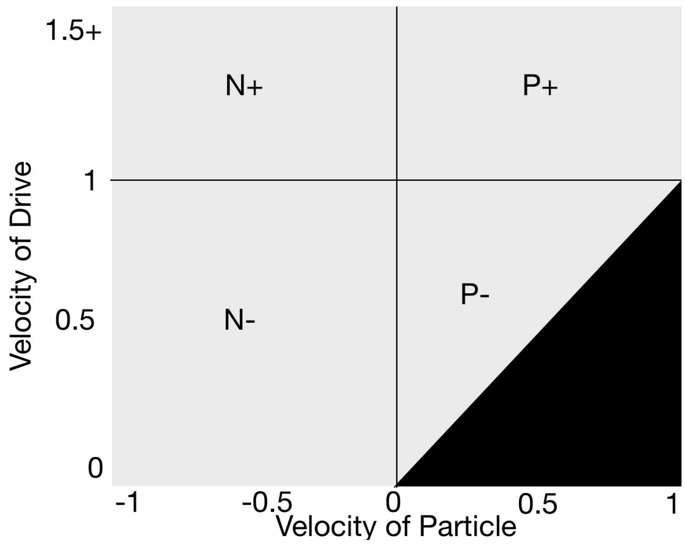

Figure 1: Figure displays the regions that define certain interactions between particles and drives of differing speeds. The y-axis is the drive velocity while the x-axis is the velocity of the particle. The velocities labeled are in fractions of the speed of light. This notation was used by the literature in order to more simply distinguish between certain interactions.

For the purpose of his study, the interactions will be occurring in the N+, N-, P+, and P- regions, as that is where all interactions would take place with particle velocities being as low as 0.001c. The essential difference between the N+ and N- definitions as it relates to particles within the bubble is the time that the matter spends in the parameters of the bubble before passing through the field, where particles within subluminal drives (an N- scenario) spend much longer time within the bubble compared to the same particle in a superluminal drive. The difference between a P+ and a P- scenario is more important to understand, as with a P- scenario the matter simply becomes ejected back out towards the direction that it came from, whereas in a P+ situation the particles become time locked at a point within the bubble given by the following equation:

$$\left|x_p(t) - x_s(t)\right| \leq \frac{R}{v_s^{1/4}(t)} \quad (3)$$

$x_p(t)$ stands for the position of the particle while $x_s(t)$ stands for position of the ship. $v_s(t)$ stands for the velocity of the ship while R stands for the radius of the warp bubble. What is important to understand at this point is that the particles that are released from a drive as it accelerates have a decreased magnitude of velocity, while particles that are released from a bubble as it decelerates have an increased magnitude. In the case of the WIMP, its speed is very low, so it is able to stay within bubbles of increased speed for extremely long times. This means that there will be a greater volume of dark matter particles that will gain in magnitude of velocity rather than lose it, as they will stay in the bubble for longer and are therefore more likely to be within it as the bubble begins to decelerate. Particles within the P+ region are also time-locked, meaning that none of the particles are moving out of the drive at all, and all will all stay within the drive up to the point where it decelerates, giving all P+ region particles a massive speed increase. As well as this, relative magnitude of velocity gained scales inversely with the speed of the particle, so the slower the initial speed of the particle, the faster the final speed comparatively as it is released from the decelerating ship. According to the computer-simulated graphs provided by the literature displaying the velocities of particles of 0.001c and -0.001c speed, it is apparent that the particles released from the Alcubierre drive as it is decelerating from the speed of 10c to at rest each grow in speed at about 2 orders of magnitudes, to around 0.1c. This interaction is visually displayed in Figure 2.

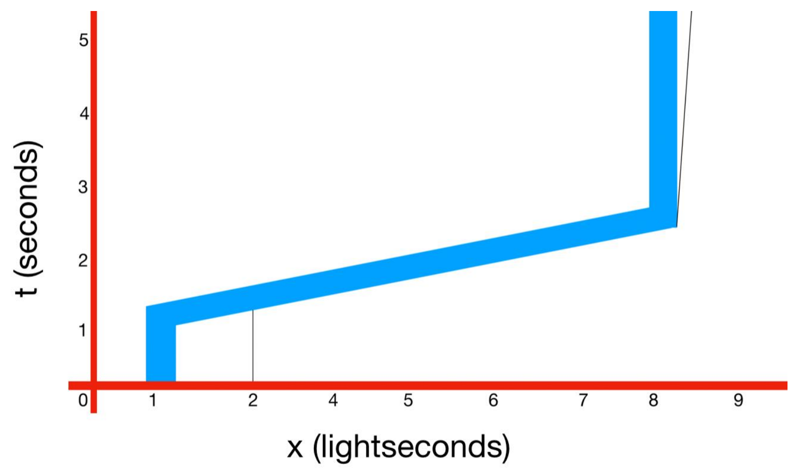

Figure 2: Graph displays a drive traveling through space (x-coordinate) and time (y-coordinate). The thick blue line displays the drive while the black line displays a dark matter particle entering the ship at 0.001c velocity and exiting it with approximately 0.1c velocity. This image is a recreation of a computer simulation graph provided by the literature adapted to better understand how interactions with dark matter would occur.

2.2 Particle Damage

Given the approximate speed that WIMPs will grow to as the drive decelerates from superluminal travel, it is possible to compute the new energy of the particles. The invariant mass of a WIMP is around 10 GeV. With a speed at around 0.1c, this gives the WIMP a kinetic energy of 8.150x10^-12 joules. This was found using Einstein's equation seen below.

$$E = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}} - mc^2 \quad (4)$$

m stands for mass (of the particle in this situation), v stands for velocity (once again of the particle). E stands for energy and c stands for the speed of light. This energy value is comparable to that of a neutrino after it has been propelled forward by a supernova explosion (12). Energy comparisons can be seen in Table 1. The table displays one small, then increasingly large Alcubierre drives. As the table displays, even a relatively small drive is able to become a weapon of mass destruction rather than a safe mode of transportation in a single lightyear of travel. Of course, as distances decrease so too would the damage caused by the dark matter particles, however even a fraction of the power produced by even the small drive is apt to cause high damage if precautions are not taken to make sure the destination is protected or that the energy is somehow diverted. Of course the larger the drives get, the more dark matter gets trapped within them. If it comes to the point where humanity seeks to move entire cities of people to nearby stars and extremely large drives are needed, then the energy produced starts to mimic a severe nuclear holocaust occurring in an instant. Much damage may be caused to all surrounding structures at the destination due to this occurrence.

Energy created in accelerated dark matter particles with the deceleration of the Alcubierre drive

Drive Size	~Energy per lightyear traveled in joules	Megatons of TNT worth of energy created per lightyear traveled
100 cubic meters	2.008x10^12 J	0.0005 MtTNT
1 cubic kilometer	9.322x10^16 J	22.280 MtTNT
10 cubic kilometers	4.327x10^17 J	103.42 MtTNT
100 cubic kilometers	2.008x10^18 J	479.92 MtTNT

Table 1

The resting mass of the WIMP in kilograms equals 1.8x10^-26. Table 2 displays how many lightyears that drives of different sizes would need to travel in order to gain the mass of known celestial objects. Even with the largest drive and the smallest object, the lightyears of travel necessary to obtain such a mass are many orders of magnitude larger than the diameter of the universe. Although gravity is unfeasibly a problem to the destination of Alcubierre Drive travel, it may begin to cause problems within the bubble given large enough journey distances. Small amounts of gravity left within areas meant to be a vacuum could cause issues with the structure of the drive. Also it may become extremely hard to defend or shield from these particles due to their nature as dark matter. Electromagnetic methods are completely useless at diverting these particles due to their nature of non-interaction through the electromagnetic field.

Lightyears of travel necessary to amass the gravity of celestial bodies from dark matter alone

Drive Size	Distance needed to obtain moon mass	Distance needed to obtain Earth mass	Distance needed to obtain sun mass
100 cubic meters	1.666x10^24 ly	1.354x10^26 ly	4.509x10^31 ly
1 cubic kilometer	3.584x10^19 ly	2.917x10^21 ly	9.715x10^26 ly
10 cubic kilometers	7.732x10^18 ly	6.284x10^20 ly	2.093x10^26 ly
100 cubic kilometers	1.666x10^18 ly	1.354x10^20 ly	4.509x10^25 ly

Table 2

2.3 Dark Matter vs. Other Particles in Space

There is six times more dark matter in the universe than regular matter. This means that under the particle models of dark matter, the damage caused by the superluminal Alcubierre drive is much higher than previously assumed when only "light matter" was taken into account. For example, when only electrons are taken into account, there is an average of 0.03 electrons per cubic centimeter of space (13). The average speed of an electron is around 0.01c. According to the particle-drive interaction graphs provided by the literature, this translates to an increase in speeds of around 0.6c. The mass of an electron is 9.109x10^-31 kg. Using equation 4 to find the average energy released per cubic centimeter, we find an average of 6.140x10^-16 joules. Comparing this to the dark matter energy produced per cubic centimeter we get 8.150x10^-11 joules of dark matter per cubic centimeter. This is an entire five orders of magnitude higher energy from dark matter particles compared to electrons. This trend persists among other electro-magnetic particles.

3. Real-Life Applications

3.1 Observer velocity's effect on WIMP particle energy

While the concept of an Alcubierre Drive is interesting, they are, at this point in time, only theoretical. Increased energy in WIMPs due to high-velocity body interaction can, however, become a very important and influential topic as it relates to real celestial bodies, including Earth. It is important to note that dark matter particles are unable to amass in places such as the center of a celestial body as they are constantly moving and are unaffected by electromagnetic interactions that could serve to slow down WIMPs like atoms are able to slow down each other. This means that a WIMP is able to pass right through the gravitational center of a celestial body without losing velocity. However, when a body is traveling at velocities higher than the WIMP particle, particles are unable to touch the body from its back. So, hypothetically, assume that the maximum WIMP velocity is 300 km/s and there is a body with a velocity of 600 km/s, traveling along a hypothetical x-axis. Only particles in front of the body will pass through it, with much higher relative velocity and therefore much higher energy. This can be seen in Figure 3.

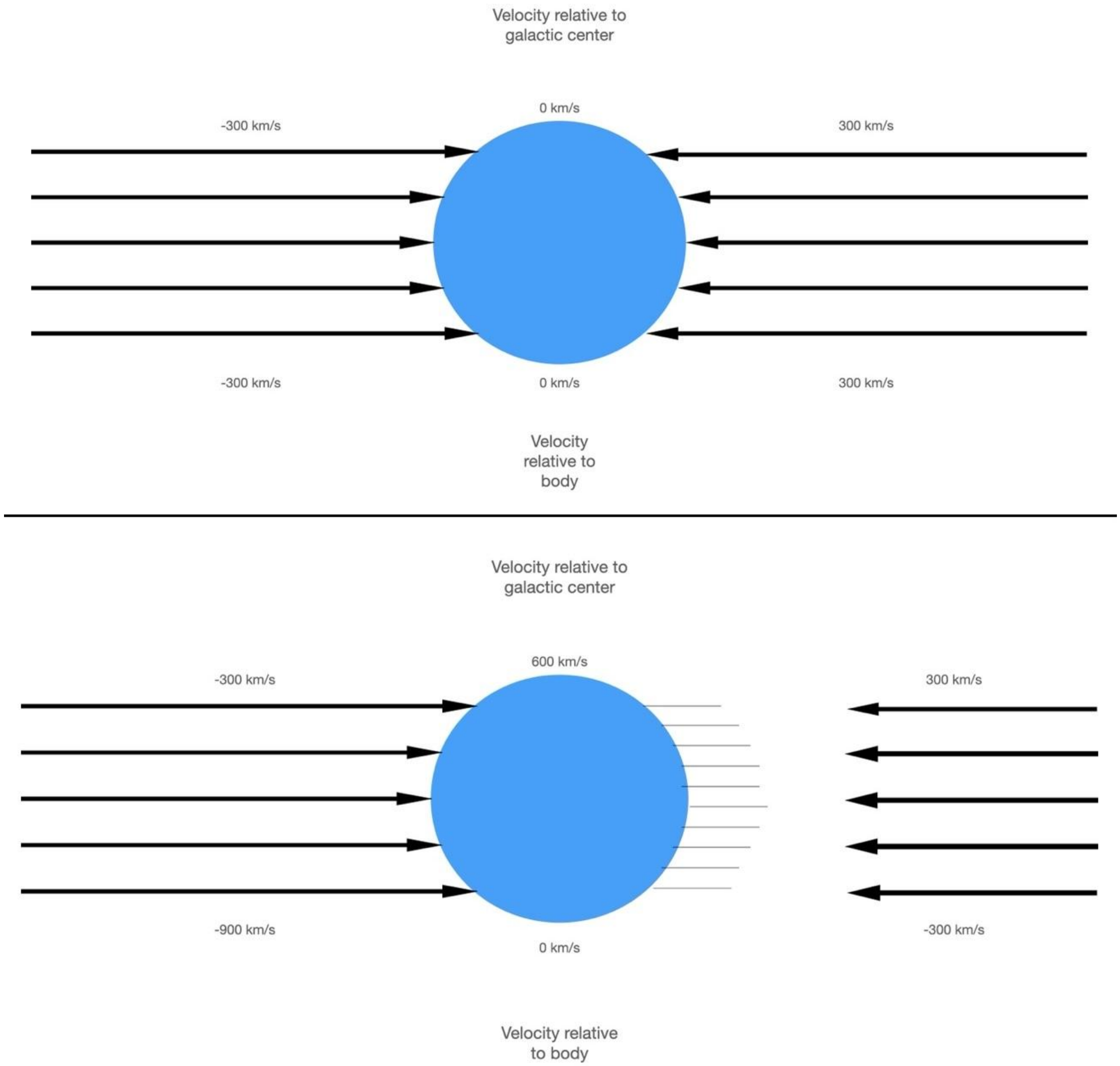

Figure 3: Figure displays a body stationary with respect to the galactic center and a body in motion with respect to the galactic center. Blue spheres represent bodies and black arrows represent dark matter particles. Both velocity with respect to the galactic center and velocity with respect to the body's frame of reference are noted.

Of course particles do not always have a perfect velocity of 300 or -300 along the x-axis, as their velocities are also split between the y and z axis, and may experience a variety of different speeds depicted by its velocity density curve. Therefore a WIMP with a maximum velocity of 300 km/s has a velocity value of any real number between -300 to 300 km/s. What this essentially means is that an object at rest with respect to the galactic center will experience all particles traveling towards it with non-zero velocities at its front and back, as there are no particles that will not catch up to it. As the body begins to move the particles it runs into at its front begin to increase in relative velocity, while those at its back decrease in relative velocity. The total velocity and therefore energy affecting the body will grow non-linearly until the body exceeds the speed of dark matter, at which point the velocity of the body will equal the average relative velocity of dark matter. This trend can be noted in Table 3, where intervals in measured velocities are set at 100 km/s and the true WIMP velocity with respect to the galactic center is set at 300 km/s as previously assumed:

Velocity of the body in question, front facing WIMPs with positive velocity (Vf), front facing WIMPs with negative velocity (Vf-), back facing WIMPs with positive velocity (Vb), and total relative velocity of the particles with respect to the body in km/s

Relative velocity in km/s of particles as they interact with a body at a set speed

Body Velocity	Vf=0	Vf=100	Vf=200	Vf=300	Vf-=100	Vf-=200	Vf-=300	Vb=100	Vb=200	Vb=300	Total Relative Velocity
0	0	0	0	0	100	200	300	100	200	300	1200
100	100	0	0	0	200	300	400	0	100	200	1300
200	200	100	0	0	300	400	500	0	0	100	1600
300	300	200	100	0	400	500	600	0	0	0	2100
400	400	300	200	100	500	600	700	0	0	0	2800
500	500	400	300	200	600	700	800	0	0	0	3500
600	600	500	400	300	700	800	900	0	0	0	4200

Table 3

The apparent trend that can be derived from Table 3 is also applicable to multiple speeds and intervals, as can be seen in Table 4, where intervals of 10 km/s with a maximum of 50 km/s are utilized:

Velocity of the body in question, front facing WIMPs with positive velocity (Vf), front facing WIMPs with negative velocity (Vf-), back facing WIMPs with positive velocity (Vb), and total relative velocity of the particles with respect to the body in km/s

Relative velocity in km/s of particles as they interact with a body at a set speed

Body Velocity	Vf=0	Vf=10	Vf=20	Vf=30	Vf=40	Vf=50	Vf-=10	Vf-=20	Vf-=30	Vf-=40	Vf-=50	Vb=10	Vb=20	Vb=30	Vb=40	Vb=50	Total Relative Velocity
0	0	0	0	0	0	0	10	20	30	40	50	10	20	30	40	50	300
10	10	0	0	0	0	0	20	30	40	50	60	0	10	20	30	40	310
20	20	10	0	0	0	0	30	40	50	60	70	0	0	10	20	30	340
30	30	20	10	0	0	0	40	50	60	70	80	0	0	0	10	20	390
40	40	30	20	10	0	0	50	60	70	80	90	0	0	0	0	10	460
50	50	40	30	20	10	0	60	70	80	90	100	0	0	0	0	0	550
60	60	50	40	30	20	10	70	80	90	100	110	0	0	0	0	0	660
70	70	60	50	40	30	20	80	90	100	110	120	0	0	0	0	0	770
80	80	70	60	50	40	30	90	100	110	120	130	0	0	0	0	0	880

Table 4

The more intervals that fit within a function, the more accurate the data becomes. In the hypothetical data displayed by the two tables, a low amount of intervals is utilized to more easily display the trend of non-linearity to linearity. This data essentially displays the concept that relative dark matter velocities acting on a body can be seen as a piecewise function where:

$$\begin{aligned} &If\ V_{WIMP} > V_{Body}\quad then\ V_{Total(n)} = V_{Total(n-1)} + 2V_{Body(n)} - V_{Body(1)} \\ &If\ V_{WIMP} \leq V_{Body}\quad then\ V_{Total(n)} = [1 + 2(V_{WIMP} \div I)]\, V_{Body(n)} \end{aligned} \qquad (5)$$

Where *I* stands for interval speeds. There are multiple reasons that this is not an exactly applicable function. First, this only accounts for particles in the hypothetical x-axis that the body is traveling through, so it is not a true total velocity, only a means to find an average velocity for WIMPs traveling along the x-axis interacting with the front and back of the body by utilizing the equation:

$$V_{Avg} = \frac{V_{Total}}{1+2(V_{WIMP} \div I)} \qquad (6)$$

Where *I* stands for interval speeds. Also, the velocity density of the WIMP is not yet well known (14). In this simulation, they have all been granted uniform likeliness of having any velocity on the x-axis, though the true density may follow the Maxwell-Boltzmann curve, or some new density entirely. The particles may also experience an increase in velocity due to gravitational infalling. Finally, the body travels through more front-faced particles than back-faced ones due to its high velocity, so there is more likely to be more front-faced interactions than what this function presents. Despite these issues, this function is still more than likely fully able to display the general trend shown in Figure 4. This is because the issues described by the limitations act as coefficients that may make differences in averages more marginal, but they do not change the overall underlying derivative trend displayed by the function.

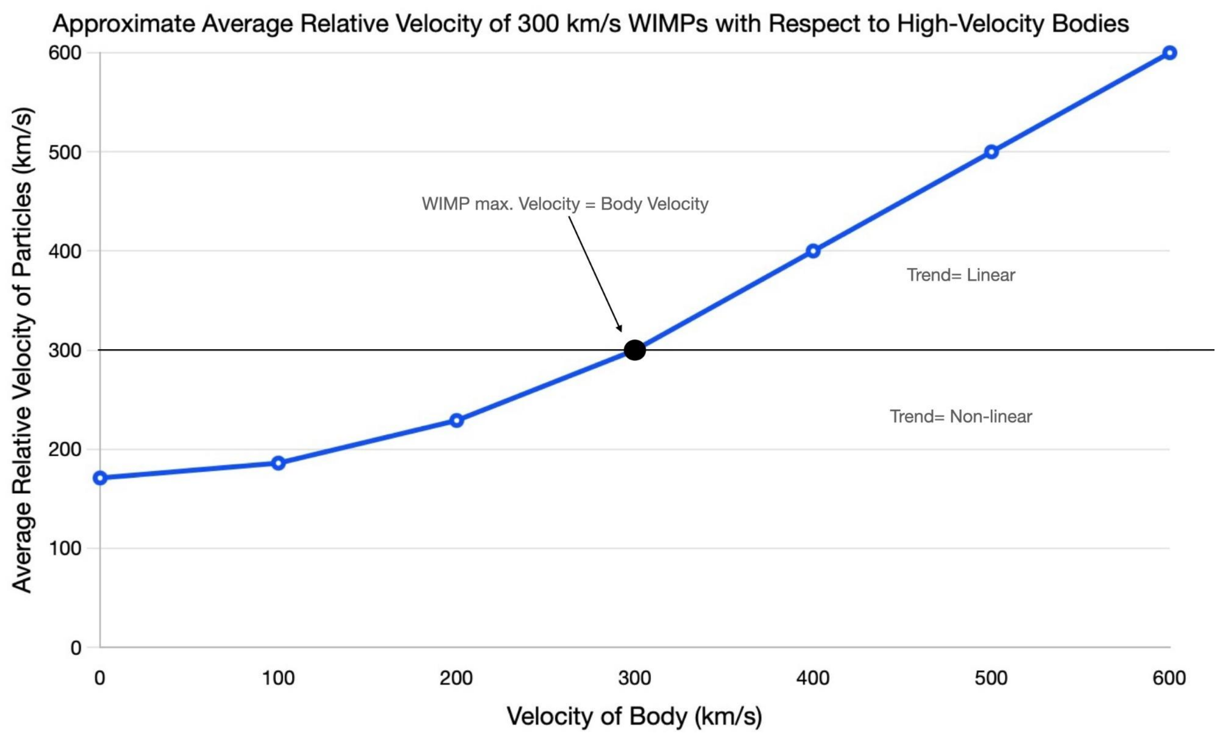

Figure 4: Graph displays multiple body velocities and the corresponding average velocity of dark matter particles interacting with it. A clear trend is displayed that proves when the velocity of a body reaches the velocity of the WIMP the increasing relative velocity is linear, whereas at lower speeds the WIMP relative velocity grows exponentially with the velocity of the body.

As can be seen from the graph, when a body is traveling through space slower than the speed of WIMPs, as its velocity increases, the average relative velocity of particles interacting with the body grows at a nonlinear, seemingly exponential rate. When the velocity of a body exceeds the velocity of the WIMP, relative particle velocity grows linearly.

One may begin to wonder what the applicational purpose of this function is if the true maximum velocity of a WIMP is not known. This is so that maximum velocity can begin to be determined using detection methods. Due to the fact that the resting mass of a WIMP is constant its kinetic energy is solely variable in terms of its relative velocity, as can be seen in equation 4, meaning that detection methods based on the energy of the WIMP are available to determine not only the existence of dark matter, but also its true speed. This is outlined in the following section.

3.2 Detection methods based on increasing average velocity.

There have previously been numerous detection methods that have attempted to discover dark matter particles, most notably the DAMA/LIBRA detector located under a mountain in Italy's Gran Sasso Underground Laboratory. The idea behind this detector is that when a WIMP particle collides with a nucleus in a concealed and well-protected sodium iodide crystal, that collision causes a scintillation that is amplified by photomultiplier tubes so that the photon emission is detectable. The point of the DAMA/LIBRA experiment is to see whether or not more scintillations will be detected from WIMP collisions as the Earth moves with the sun through the galaxy. Although the data from this experiment holds true to this prediction, the results from DAMA/LIBRA are highly controversial. Using equation 5, a new idea takes place that allows for an experiment that doesn't just account for the number of flashes per month of the year, but instead the “brightness” of those flashes.

This is due to the fact that the resting mass of the WIMP is held constant, so the only thing that increases its energy is an increase in its velocity. This increase in velocity has been modeled, so its change in energy would be directly proportional to a translation from equation 5. Because the amount of photons released by a nucleus during a scintillation event is based on the amount of energy put into that nucleus, the average energy of particles interacting with the nuclei in a detector is able to be determined by finding the number of photons emitted per scintillation (though it must be taken on a square-root factor as energy increases based on velocity squared, as can be seen in equation 4) (15). This detection of the change in photon quantity is certainly realizable, as when the scintillations are amplified by the photomultiplier tubes, the resulting electric pulse created by the tubes is proportional to the initial photon number. The read must therefore be based on the strength of the pulse rather than the number of pulses detected.

If the degree of photons emitted with each scintillation was found to increase linearly (with aforementioned factors taken into account) as the months move from November (when the Earth moves the slowest through the galaxy as compared to the galactic center) to June (when the Earth moves the fastest) then that would mean that the Earth moves at a velocity higher than the maximum speed of dark matter, whereas if the flashes display an increase in photon emittance in a non-linear and seemingly exponential fashion, that instead means that the Earth is moving slower than the speed of dark matter. Should this experiment take place, it would allow not only for further proof of the existence of dark matter WIMPs but also for the beginning of an understanding of the maximum speed of the WIMP.

4. Conclusion

The dark matter model of the WIMP is theorized to make up the majority of matter within the universe, and its effects on Alcubierre drives are certainly noticeable. Interaction with the Alcubierre drive allows for what was once a very neutral and low particle to act as invisible beams of destruction. The dark matter amassed from intergalactic travel would cause great damage to systems within even the closest galaxy, Andromeda. It is, of course, noted that there is much less dark matter within the intergalactic medium, however even travel through one galaxy would begin to cause many issues to the destination. The gravitational effect of the particles also may become an issue as distances become incredibly long, however, these journeys are unrealistic due to the unbelievable magnitude necessary to realize their effect. Gravity may, however, become an issue to the structure of the drive itself as unanticipated forces of gravity interact with each other. This study has also proven that dark matter particles have an effect from Alcubierre drive interaction multiple orders of magnitude larger than the effect of particles of regular matter such as electrons (not including electromagnetic damage). In essence, the effect of an Alcubierre drive on particles of dark matter can be seen as akin to the effect of a supernova on neutrinos. The particles are originally low energy and harmless. The particles don't interact with electromagnetism and are invisible. After the “event” happens, whether it be a supernova or a drive’s deceleration, the particles increase in flux and speed dramatically, causing invisible destruction to their destination. One drawback of this study is the fact that we simply don't know much about dark matter at all. Due to the sheer lack of knowledge that the scientific community has on these particles, results could be off by as much as a few orders of magnitude simply because the true mass, abundance, and speed of these particles, and even if they exist or not, is simply not well known. That is why the second portion of this study has created a model that attempts to affirm more information about the WIMP. A function has been modeled that is based upon the speed of a body moving through a galaxy that determines the approximate average relative velocity of particles at its front and back. This allows for a trend to be defined where if the increase in relative particle velocities in a body is linear as the speed of the body increases, then the maximum velocity of a WIMP is less than the velocity of the body. If it is non-linear, the maximum velocity of the WIMP is larger than the body. Were this notion applied to a detector similar to DAMA/LIBRA, where instead of the number of scintillations being measured, the degree of brightness from those scintillations was measured, then the trend found in the functions would be directly applicable to real life. If the brightness of scintillations (with adjustments to account for the squared increase in energy based on velocity) was found to increase linearly with the increasing velocity of the planet, then that would mean the planet is traveling faster than the speed of the WIMP. If it increases non-linearly it is moving slower than the speed of the WIMP. This detection method not only allows for increased evidence of dark matter WIMP existence but also allows for an estimate on the speed of the WIMP. This function and method were inspired by the effects of WIMPs on Alcubierre Drives based on an assumption about the speed of the WIMP, however, it is this detection method that could help the scientific community learn more about the speed of the WIMP, giving more accurate data to learn about the effect Alcubierre drives could have on them.

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