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The Matter-Antimatter Dipole

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Physicists have known that mechanical forces can be described by a set of equations that are similar to Maxwell's equations since Oliver Heaviside first proposed it in 1893.[1] His and most subsequent theories attempt to combine gravity with electromagnetism, but run into difficulties because there is no negative mass or negative gravity to form a dipole analogous to the electric charge dipole. Gravity also works in the wrong direction. In 1930 Paul Dirac interpreted the solutions to the equation bearing his name as forms of positive and negative energy, even though there is no negative energy in standard physics theory. A few years later these were identified as matter and antimatter. His speculative thoughts on the behavior of this positive and negative "energy" were analogous to the characteristics of a dipole.[2] In the years that followed we have learned that all forms of matter exhibit short-range repulsion, which is normally attributed to the Pauli exclusion principle. Additionally, matter and antimatter can be thought to have a strong short-range attraction just prior to annihilation. As such, matter and antimatter are known to participate in force interactions consistent with a dipole, and this paper examines some of our scientific knowledge that supports the existence of the matter-antimatter dipole.

1. Introduction

While mechanical forces are not normally listed as one of the four fundamental forces of the standard model, physicists have nonetheless attempted to unify mechanical forces and electricity and magnetism into a single theory. The first attempt, and perhaps most notable was made by Oliver Heaviside, who is best known as the mathematical physicist who developed the notation reducing the 20+ equations originally related by James Clerk Maxwell into the four Maxwell's equations we know today.

Heaviside recognized that gravity can be expressed in notation that is analogous to his simplification of Maxwell's equations, however operating in the opposite direction.[1] As for the magnetic effects of gravity he wrote:

> *"Now what is there analogous to magnetic force in the gravitational case? And if it have its analogue, what is there to correspond with electric current? At first glance it might seem that the whole of the magnetic side of elctromagnetism was absent in the gravitational I analogy. But this is not true."* [1]

Heaviside goes on to detail how gravity can be thought to have a magnetic component analogous to the magnetic fields of electromagnetic theory. This was the birth of the theory of gravitomagnetism, which has since been developed by numerous other scientists.[3][4][5][6] It has, however, never achieved mainstream acceptance due to two major inherent difficulties. The first is that the force acts in the wrong direction since matter is attracted by matter due to gravitation rather than repelled in a manner analogous to the repulsion between electric charges of the same sign.

The second difficulty is that unlike electromagnetic theory, which has at its heart the positive and negative electric charge dipole, there is no dipole for gravity. There is no negative gravity or alternatively, no negative mass. Even so, these theories have led to much speculation about the existence of negative gravity, or antigravity as it is popularly called, and speculation about the possible existence of negative mass.

The discovery that the rate of the expansion of the universe is accelerating gives us a whole new way to look at the relationship between mechanical and electromagnetic forces, as that acceleration means that there must be a force responsible for it, a force that causes matter to move away from matter at intergalactic distances. This opens up the possibility that mechanical forces between electrically neutral bodies of matter can be described by a system of equations analogous to Maxwell's equations. But in order for that to work there must be a non-electric dipole of some sort, and to date mass does not appear to be an acceptable candidate for that dipole.

The search for the non-electric dipole takes us back to the positive and negative energy solutions of the Dirac equation, as Dirac interpreted the solutions to his equation of the electron.[2] His negative energy solution was soon recognized as a prediction of the positron, the first known antimatter particle. Since then the properties of matter and antimatter are treated as something intrinsic to particles, and Dirac's interpretation of them being a type of positive and negative energy is generally ignored. We will examine Dirac's interpretation in more detail as his explanation of the negative and positive energy is consistent with a dipole interaction.

Even more importantly we can examine the interactions between matter and antimatter forms of the three particles that make up all the known stable matter in the universe, and see that like particles exhibit a strong short-range repulsive force. This force is normally attributed to the Pauli exclusion principle. Since matter and antimatter particles of the same type annihilate with one another, we can also think of them as exhibiting a strong short-range attraction.

These short-range forces are well known to physicists; however, it is not pointed out that matter repelling matter and matter attracting antimatter is the basis for a non-electric dipole occurring between all matter and antimatter.

2. Dirac's Positive and Negative Energy

Paul Dirac wrote a paper in 1930 where he attempted to address the nature of the negative solutions of the Dirac equation of the electron.[2] His equation predicted an electron with energy of less than or equal to negative $\mathbf{mc^2}$, in addition to the normal electron with energy greater than or equal to positive $\mathbf{mc^2}$ where **m** is mass and **c** is the speed of light.

Dirac recognized that the negative solution must have positive charge and must annihilate when combined with an electron, but as he later admitted, he was not brave enough to predict the existence of the positron. Instead he speculated that it was a proton, an idea that was easily disproved.

With the discovery of the positron two years later it was clear that his paper predicted the positron. The electron and positron are then some form of opposing energy, which we have come to call matter and antimatter. Over time the problem of the positive and negative energy solutions was set aside and matter and antimatter are usually treated as intrinsic properties of particles. Little progress has been made in understanding the nature of Dirac's negative energy.

In an attempt to make sense of negative energy electrons, Dirac imagined a sea of them occupying all possible states under the Pauli exclusion principle except for an occasional vacancy or hole. This became known as the Dirac Sea. He ascertained the following:

"Thus the hole or vacancy in a region that is otherwise saturated with electrons is much the same thing as a single electron in a region that is otherwise devoid of them."

He went on to consider:

"…the holes should be counted as things of negative energy since to make one of them disappear (i.e to fill it up) one must add to it an ordinary electron of positive energy. Just the contrary holds, however, for the holes to be negative energy electrons. These holes will be things of positive energy and will therefore be in this respect like ordinary particles. Further the motion of one of these holes in an external electromagnetic field will be the same as that of a negative energy electron that would fill it and will thus correspond to its possessing a charge of +e. We are therefore led to the assumption that the holes in the distribution of negative energy electrons are protons. When an electron with positive energy drops into a hole and fills it up, we have an electron and proton disappearing together with the emission of radiation."

As we now know, Dirac's holes are not protons, but rather positrons and they can be best thought of as real particles rather than holes. Positrons do have positive charge and annihilate with electrons as Dirac predicted.

Dirac's imaginings bring up the basic concepts that both positive and negative energy electrons cannot occupy the same state, including position in space. Positive energy electrons can be thought of as being repelled from other positive energy electrons in order to comply with the Pauli exclusion principle. Negative energy electrons likewise repel one another. On the other hand, electrons and positrons naturally cancel each other out, annihilating and leaving behind a neutral energy region in space. From his ideas, a picture emerges of a dipole-like interaction, where like energies repel and opposite energies attract.

Energy is normally thought to always be zero or positive and not negative. So instead of considering negative energy electrons, it is preferable to think of positive energy positrons, in that way we can dismiss the problem of the negative energy solution. But can we really dismiss it, or is there some deeper understanding waiting to be discovered? It seems likely that we have more to learn about it and the positive and negative energy solutions appear at the very least to be indicative of a non-electric dipole.

3. Evidence of Matter Repelling Matter

For each of the three particles that make up the stable matter in the universe, we have convincing evidence that they repel each other. The most obvious form of repulsion is said to derive directly from the Pauli exclusion principle leading to degeneracy pressure. Degeneracy pressure between neutrons for example, determines the density of neutron stars, while proton degeneracy pressure and electron degeneracy pressure are important in white dwarf stars.

Freeman Dyson showed that degeneracy pressure between electrons leads to the short-range repulsive force responsible for the solidity of matter.[7][8][9] This short-range force is stronger than Coulomb repulsion which had previously been considered the cause of the apparent solidity of matter. In this manner, it is known that there is a pressure causing each of the three most common particles with mass to repel other particles of the same type.

Strong short-range repulsion is also seen as part of the strong nuclear force, as the strong nuclear force not only includes a force that overcomes Coulomb repulsion, but at ranges on the order of 0.7 femtometers, nucleons are repelled from one another.[10] One school of thought is that this strong force repulsion between protons is also due to the Pauli exclusion principle, as is the repulsion between neutrons. But there is also short-range repulsion between protons and neutrons.

Protons and neutrons are not known to occupy the same physical location or combine to form another type of particle. As such there must be a basic physical explanation for why they remain separated. Regardless of the explanation, the result is that they are effectively repelled from one another. One possibility is that since a neutron forms when a proton and an electron combine, it is not possible to add another proton. This could be thought of as an extension of the Pauli exclusion principle.

Another important interaction occurs between a proton and an electron. Once again this is not a direct consequence of the Pauli exclusion principle, at least not in its standard form. Of the four fundamental forces, the principle one that governs proton-electron interactions is Coulomb attraction. But if Coulomb attraction were the only force then electrons and protons would always combine to form neutrons and there would be no hydrogen, or any other atom.

There is a known potential barrier between protons and electrons that prevents an electron from simply falling into a proton, or vice versa. The potential has been measured to be ~780 kilo-electron-volts (KeV). Consequently, in order to combine, the particles need to either be energetic enough to overcome this potential, exceeding 780 keV, or there needs to be a quantum tunneling process that allows them to combine without exceeding that energy. Once the potential barrier has been breached, a proton and electron readily form a neutron. But at lower, energy this potential barrier is effectively a repulsive force.

The last interaction to consider between the basic three particles is between neutrons and electrons. Since electrons are normally at a distance from the neutrons in atoms, there is little discussion of short-range interactions between them. We do know however, that electrons do not collocate with neutrons such that they would form an additional type of particle. This situation is analogous to the one between protons and neutrons. We simply cannot add an electron to a neutron. As such there is effectively a short-range repulsion between them.

The known science shows us that there are interactions between each of the three most prevalent particles with mass, which equate to a repulsive force or potential between matter. This repulsive force can be thought of as a generalization of degeneracy pressure theory due to an extended Pauli exclusion principle. However, based on the Dirac solutions it may be better to think of it as a more fundamental phenomenon due to interactions between positive-energy matter particles.

Based on the known symmetry between matter and antimatter, we must also conclude that antimatter versions of each of these three particles must interact the same way with other antimatter particles. So, there is a short-range repulsive force between antimatter as well.

4. Evidence of Matter Attraction to Antimatter

As Dirac predicted, a positron annihilates with an electron. They release energy in the form of two photons. Similarly, all antimatter particles annihilate with their matter opposite, so a proton annihilates with an antiproton and a neutron annihilates with an antineutron. Electrons and positrons have opposite charge as do protons and antiprotons.

Neutrons and antineutrons are largely neutral, however, neutrons are known to have a charge distribution, so that will affect interactions between them. Neutrons and antineutrons must have the opposite configuration and thus experience a small amount of Coulomb attraction. That said, we would expect there to be a much stronger force that brings them together the instant before annihilation.

We can also hypothesize that there is a short-range attractive force between electrons and positrons and protons and antiprotons that is equal but opposite to degeneracy pressure. In any case, there is no doubt that these particles are drawn together in the instant before annihilation. This attractive response, regardless of the underlying physical mechanism, is in opposition to the repulsion between like particles.

We can also consider that when a positron interacts with a neutron, the positron is captured and the neutron decays to a proton. Similarly, when an antiproton interacts with a neutron it is captured and the neutron decays leaving an electron. We can think of the moment of capture as effective evidence of a short-range attractive phenomena. It is definitely the opposite effect from repulsion, regardless of how we describe what is happening at that instant. Electrons and protons are similarly captured by antineutrons.

The last two particle interactions to consider are positrons and protons, and electrons and antiprotons. Because these particles have the same electric charge, positive in the first case and negative in the second, electric charge dominates the interaction over long-range distances. There does not appear to be much discussion about a possible short-range attractive or repulsive force between these particle combinations.

The best evidence for a short-range attractive force between a proton and positron is the existence of the Delta baryon with +2 charge. It decays into a proton and a positive pion and the positive pion decay includes a positron. The reverse process must also occur, such that a proton and positron can combine given sufficient energy to produce a +2 charge delta baryon. This is indicative of some form of short-lived short-range attraction. The anti-particle of the +2 delta baryon has a -2 charge and can similarly be thought to show a short-range attractive potential between an antiproton and an electron.

The charmed sigma particle with +2 charge also includes a proton and positron in its decay chart, and there are a couple other +2 charge particles that do as well, with their -2 charged antimatter versions being indicative of a short-range attraction between the electron and antiproton.

At the very least, the positron and proton, and electron and antiproton are not subject to the Pauli exclusion principle, and as such there is less of a pressure force between them than particles that are. That alone produces something of a very short-range dipole-like effect, noting that the Coulomb force still dominates longer-range interactions.

It is clear from reviewing the basic physical evidence of matter-antimatter interactions between each of the three most common particles with mass and their antimatter opposites, that each interacts in a manner consistent with a short-range attractive phenomenon.

5. Is this an Electric Phenomenon?

The first test of a matter repulsion and matter-antimatter attraction hypothesis is to make certain that it is not merely a secondary effect due to electric charge. To that end, we will review the phenomena.

Neutron repulsion of a magnitude equivalent to degeneracy pressure is most obviously not due to electric charge as the particles are electrically neutral. Even though neutrons are known to have a charge gradient, the repulsive force deriving from that is much smaller than the force due to degeneracy pressure. Neutrons also exhibit short-range repulsion in the nucleus with each other and with protons that cannot be explained as a Coulomb force.

Protons similarly exhibit short-range repulsion. In this case, it is much stronger than the attraction due to the strong nuclear force, and the strong nuclear force is on the order of one hundred times stronger than the Coulomb repulsion. Consequently, the short-range repulsive force is much greater than the Coulomb force. The short-range repulsion between electrons normally attributed to the Pauli exclusion principle is similarly much greater than Coulomb repulsion.

The forces between protons and electrons are particularly important with respect to differentiating matter interactions from electric interactions. The ~780 keV potential barrier between them opposes the Coulomb attraction that would otherwise push them together. It is not possible within current electromagnetic theory for this potential barrier to be due to Coulomb forces.

The last short-range force we must consider is between electrons and neutrons. Since the neutron is electrically neutral, the Coulomb potential is very small. The simplest particle that forms by combining those two particles is the -1 charge delta baryon. Forming the -1 delta baryon requires substantial additional energy, much greater than what could be accounted for by Coulomb forces. The potential barrier to -1 delta formation is on the order of the rest mass-energy of a proton or neutron, which is much greater than the Coulomb potential and in some respects analogous to the potential barrier between electrons and protons.

As with short-range repulsion it is clear that short-range attraction between matter and antimatter is not a Coulomb force when we consider interactions with neutrons and antineutrons. These include:

1. Neutron-antineutron annihilation
2. Positron-neutron annihilation yielding a proton
3. Antiproton-neutron annihilation yielding an electron
4. Proton-antineutron annihilation yielding a positron
5. Electron-antineutron annihilation yielding an antiproton.

In each case, there is insufficient Coulomb attraction to cause the particles to come together and annihilate. Within the scope of current theory these interactions occur when the particles get close enough due to their kinetic motion so that a weak interaction occurs leading to annihilation. To date it has not been shown experimentally that matter and antimatter are attracted due to gravity, or by extension, attracted by a force other than the weak interaction. Though in each case, energy is emitted in a manner that is opposite from the effect of a potential barrier. In this respect, the weak interaction leading to annihilation can be thought of as an attractive force.

In the case of annihilation of electron-positron pairs and proton-antiproton pairs the Coulomb potential may be adequate to explain the interaction. It would, however be worth examining interactions to see if their motion is accelerated at short-range in a manner which is greater than expected due to Coulomb attraction alone.

The last two interactions to consider occur between the positron and proton, and electron and antiproton. As stated previously, given sufficient energy to overcome Coulomb repulsion they can form the +2 delta baryon and -2 anti-delta baryon respectively. In many respects, this is like neutron formation as it involves a weak interaction. The weak interaction can be thought of as an attractive potential, but there is currently no evidence of an additional attractive force.

It is clear that short-range repulsion between these three particles is not due to Coulomb forces. Weak interactions are by their nature not strong enough to account for the repulsion. As far as matter and antimatter interactions go, it is not clear from experiments done to date if there is an attractive force in addition to Coulomb attraction and weak interactions.

Short-range repulsion is not due to Coulomb forces and the repulsive force based on the Pauli exclusion principle alone is sufficient to lead to non-electric matter-antimatter dipole behavior. As such we must consider the matter-antimatter dipole as being independent from the electric charge dipole.

6. Electron, Proton and Neutron Dipoles

One interesting particle property that is a direct consequence of the existence of a matter-antimatter dipole, is that each matter-antimatter particle pair can have one of three matter and electric dipole orientations. The first is the electron-like orientation where one particle is matter with negative electric charge and the other antimatter with positive electric charge. The second is proton-like where the matter particle has positive electric charge and the antimatter particle has negative electric charge. The third possibility is neutron-like where both the matter and antimatter particles are electrically neutral.

Electron-like and proton-like particle pair dipoles (i.e. electron-positron and proton-antiproton) always repel each other, as in one orientation they repel due to electric charge and in the other they repel due to their matter-antimatter orientation. As such, in a quantum field of virtual particles containing both electron-like and proton-like particle pairs, there exists a constant van der Waals based pressure exerted in all directions. Such a van der Waals force should decrease less rapidly with distance than other van der Waals forces, perhaps even following the inverse square law.

More generally, a van der Waals theory involving interactions between dipoles with both an electric dipole and a matter-antimatter dipole must be developed.

7. Matter Charge Discussion

The existence of repulsion between matter particles and attraction between matter and antimatter is in many ways similar to electric charge. Matter can be thought of as a positive charge and antimatter as a negative charge. We can think of matter charge in much the same way we think of electric charge.

This allows us to mathematically describe matter-antimatter interactions with equations that are analogous to Maxwell's equations, as first considered by Heaviside. But instead of combining electromagnetism with gravity, which is exerted in the wrong direction and has no dipole, matter and antimatter have a dipole and the forces are exerted in the proper direction. Like matter-charges repel and opposite matter-charges attract. The equations for a matter-antimatter interaction have the same sign as their analogous electromagnetic equations.[11]

This treatment is also consistent with the positive and negative energy solutions of the Dirac equation. The positive energy solution behaves like a positive matter-charge and the negative energy solution behaves like a negative matter-charge.

The matter-charge dipole can be thought to arise due to the Pauli exclusion principle and annihilation. Or, perhaps more fundamentally it can be thought of as a property of Dirac's positive and negative energy solutions and ultimately the underlying physical explanation of the Dirac result.

8. Electric Charge Discussion

Matter behaves like a type of charge separate and distinct from electric charge, but the existence of matter-charge makes us ask if the two are in some way related? Within the scope of the standard model, electric charge is unexplained. In most particle theory, including the Dirac equation, charge is treated as an intrinsic property. The constant **e** for charge is inserted into equations with no attempt made to derive it from more fundamental principles.

That said, there have been attempts to describe charge as something else. In many cases the charge of the electron is treated as a collection of smaller charges, without actually attempting to address the existence of electric charge in a more fundamental way. The quark theory introduced fractional charges which makes the problem of the fundamental origin of charge even more difficult to solve.

Dirac's description of holes in the quantum field gives us another way of looking at electric charge, as charge can also be thought to behave like a type of positive and negative energy. Positive and negative charge seek to cancel each other making space electrically neutral, in the same way that matter and antimatter particles annihilate. On the other hand, positive charges seldom combine except temporarily such as in the case of the proton and positron considered earlier. Like charges generally tend to move away from each other. So perhaps electric charge is also due to a physical effect analogous to those responsible for the Pauli exclusion principle and annihilation.

9. Conclusion

It is clear from known physics that matter and antimatter behave in such a way that matter is repelled from matter at short-range and by extension, antimatter is repelled from antimatter. It is also clear that at short-range, matter and antimatter attract. In combination, these phenomena tell us that a matter and antimatter dipole behaves in a way that is at some fundamental level similar to an electric charge dipole. As such we should see a full range of phenomena that are consistent with a matter-antimatter dipole.

This interaction is consistent with Dirac's interpretation of the positive and negative energy solutions of the equation he developed. It is also consistent with the existence of degeneracy pressure and nuclear forces that are arise due to Pauli's exclusion principle. There are also repulsive forces between different types of matter particles that indicate that we are dealing with something more general than the exclusion principle.

Heaviside's idea that mechanical forces can be described in a manner that is consistent with Maxwell's equations is viable if we incorporate the matter antimatter dipole and dark energy into the theory instead of gravity. In this manner, the dipole accounts for certain types of attraction and repulsion as well as magnetic-like effects. The matter-antimatter dipole also leads to matter-antimatter van der Waals forces, and a new type of van der Waal force that occurs due to having two charge types for every particle pair dipole.

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