the general science journal

The Origin and Arrow of Time, Dirac's Negative Energy, and Matter

Ray Fleming
101 E State St. #152 Ithaca NY 14850
rayrfleming@gmail.com

Among the most important problems in physics are questions about the origin and arrow of time, the negative energy solution to Dirac's equation, and the explanation for the preponderance of matter in the universe. This paper shows that these problems are partially linked together. The most fundamental physical presence of time in space is found in the frequencies of the quantum fluctuations of standard model quantum field theory. In particle theory, as usually expressed in Feynman diagrams, antimatter moving forward in time is equivalent to matter moving backwards in time, telling us that the questions of the arrow of time and matter/antimatter are related. And, since antimatter is a negative energy solution of the Dirac equation, negative energy correlates to a negative time arrow. Electric charge also ties in since charge changes sign between matter and antimatter and a positive and negative time arrow. The strong relationship between energy, frequency, time, matter/antimatter, and electric charge tells us that there should be a more general Dirac equation tying them all together. Even with all that information being generally well understood, we will need to determine how electrons and protons are produced to solve the preponderance of matter question.

1. Introduction

Many of the most elementary unresolved questions in physics involve time and matter, with perhaps the most elementary being the question of what is the origin of time? Related to that is the question of the origin of the arrow of time. It should not be surprising to those familiar with time symmetrical particle interactions in Feynman diagrams that there is also a relationship between the time arrow and the properties of matter and antimatter. The solutions to all of these problems are linked.

The question of the origin of time is the simplest to answer, since the standard model of physics includes a description of the most elementary occurrence of time in the most fundamental substance that fills all space. That substance is the quantum field of standard model quantum field theory. Each quantum oscillation has energy, and a related frequency and wavelength. None of these three properties can be determined independently of the others. In free space when one is set the other two are uniquely set as well.

Quantum fluctuation frequencies are the most elementary expression of time in space while quantum fluctuation wavelengths are the most elementary expression of physical dimensions of space. Thus, the quantum field gives space its physical dimensions and its property of time. That, of course, leads to the more elementary question of how do quantum fluctuations come to have a frequencies and wavelengths which is dealt with in a later section.

It is well known that for quantum fluctuations the frequency multiplied by the wavelength equals the speed of light. The frequency is also related to energy by Max Planck's equation of the quantum harmonic oscillator where the energy ($\boldsymbol{E}$) equals Planck's constant ($\boldsymbol{h}$) multiplied by the frequency ($\boldsymbol{f}$), $\boldsymbol{E = hf}$.

In quantum field theory, quantum fluctuations are described as particle pairs. Based on the existence of the Casimir effect and the quantum van der Waals forces responsible for the Casimir effect, those particle pairs are known to behave as Dirac-Fermion particle pairs. That is, they are described by Dirac's equation and Fermi statistics. The best understood Dirac-Fermion particle pair is the electron-positron pair, so it is insightful to study that example when we make an effort to understand quantum fluctuations.

When Dirac discovered the equation bearing his name, he found that it had two solutions, a positive energy solution that equates to the electron and a negative energy solution that equates to what we now call

a positron. Because of this he is credited with predicting the existence of the positron.

From his equation he confirmed the rest energy (E) of the electron is, as expected, $E = m_e c^2$, where m_e is the rest mass of the electron. The energy of the positron is $-m_e c^2$ per his equation. In all normal standard model branches of physics there is no such thing as negative energy. The problem of Dirac's negative energy has never been considered solved. The negative energy solution is called antimatter and left at that.

One of the many principles that physicists rely on when analyzing Feynman diagrams is the principle that an antimatter particle moving forward in time in a Feynman diagram behaves like a matter particle moving backward in time. This allows for certain particle interactions to be time symmetric. While well-known even before Feynman came up with his diagrams it has not been well established how the question of matter versus antimatter relates to the arrow of time problem. As we shall see, Dirac's equation neatly ties these questions together and provides the answer.

2. What is Dirac's Energy?

It turns out that the pivotal question to answer is determining the nature of the positive and negative energy results of the Dirac equation. We can think of it as Dirac's energy or matter-energy since it does not fit our standard definition of energy where energy is never negative. That leaves us with the question, what is Dirac's negative energy?

Returning to the quantum oscillator $E = hf$, Planck's constant essentially operates as a scaling factor for converting frequency to whatever preferred unit of energy has been selected for a given purpose. Therefore, we can select a set of natural units in which h is a dimensionless number equal to 1. In those units $E = f$. Energy equals frequency.

We can extend this definition for energy such that all forms of energy can be preferentially described in terms of frequency. And, the argument can be made that it is more fundamental to always think of energy in frequency terms.

If we extend this concept to the solutions of Dirac's equation, we can consider those solutions to be positive and negative frequencies, instead of positive and negative energy. So, we have $f = m_e c^2$ for the electron and $f = -m_e c^2$ for the positron, in natural units. So, this changes our question from what is negative energy to what is negative frequency?

The negative energy or negative frequency solution equates to antimatter instead of matter. We can also state it as $-f = m_e c^2$ in terms of an electron moving backwards in time, since antimatter behaves like matter moving backwards in time. Having a negative frequency changes the time arrow of a particle.

Negative frequency is also non-standard, so the physical interpretation of what it means for something to have negative frequency remains to be determined. A change in the direction of the propagation of time—arrow of time—still gives us a general way to consider negative frequencies.

We can also note that changing to negative frequency changes the electric charge from negative to positive telling us that the sign of charge is related to the arrow of time and the sign of the frequency. So, the difference between a positive and negative polarizing particle is the due to a change in the time direction of its oscillation. Therefor electric charge and matter/antimatter are properties of a single oscillator of some kind. While it is a simple matter to mathematically model this it is a bigger challenge to understand what it means physically.

We must think of negative frequency as having the same magnitude as positive frequency but traveling in the opposite time direction. The known fact that antimatter behaves like matter moving in the opposite time direction is not a bug. It is the basic underlying physical and mathematical explanation of the difference between matter and antimatter.

While somewhat impractical due to its small size, we could use the inverse of an electron's natural frequency ($f_e = m_e c^2/h$), the frequency of the Compton wavelength of the electron ($f_e = c/\lambda_e$), as a more fundamental unit of time, rather than the arbitrary unit used today. Based on the Dirac equation it is the universal unit of time. It can be termed an electron-second, which we could designate as s_e and which equals 8.093299788 x 10^{-21} seconds as computed from the Compton wavelength and speed of light. One could argue for Planck time instead, but the author will defer the argument against that for another paper.

3. The Arrow of Time and Preponderance of Matter Problems

The above interpretation of the negative energy solution to Dirac's equation tells us something important about the arrow of time. An object made of

matter has positive frequency and propagates in a positive time direction. An object made of antimatter has negative frequency and propagates in a negative time direction. Consequently, antimatter will appear to be matter to an observer made of antimatter who is experiencing time in the negative time direction.

That means that the clock of an observer, when both the clock and observer are made of antimatter, will propagate in the negative time direction. But the observer will be unable to tell that he or she is experiencing time with a negative time arrow. Instead an antimatter observer in an antimatter universe would think that they are composed of matter and are experiencing time with a positive time arrow in a matter universe. Their universe would appear no different than a matter universe appears to observers made of matter with clocks composed of matter.

In this way our universe could be composed entirely of matter or entirely of antimatter and we would be unable to tell the difference. The arrow of time always points in the matter direction, because the frequency always propagates in the positive time direction from the observer's perspective, assuming the observer is made of the same type of matter.

This does not answer the question as to how the universe is composed primarily of matter or antimatter. It merely tells us that we could not tell the difference between a matter universe and an antimatter universe as we would always think we are in a matter universe.

4. Matter Production

How is the universe predominately matter—or antimatter—rather than a combination of the two? The standard model has no accepted explanation. Most physicists think that electrons and protons where produced, rather than existing for infinity, so once we understand how they are produced we should hopefully be able to answer the preponderance of matter question.

The electrical neutrality of the universe tells us that electrons and protons, assuming they are produced, are produced in equal numbers. That tells us that they are produced by events with identical or nearly identical probabilities, or they are produced together in the same event. It seems most likely that they are produced together, as even the slightest difference in production rate would lead to a large net difference in electric charge within the universe. In an electrically charged universe electromagnetic forces would overwhelm gravitational forces. Note that electron and proton production is discussed in greater detail in a prior paper.[1]

We can think of protons and antiprotons in a similar way as electrons and positrons. They are particles with positive and negative electric charge with positive and negative frequency—time. The charge polarity is simply reversed versus the electron and positron case. With protons the relationship between energy/frequency, matter/antimatter, and positive/negative electric charge is similar to electrons only with the charge sign reversed. Yet somehow this leads to a vastly different mass-energy, wavelength and frequency.

We can then consider the idea of an extended Dirac equation with four solutions as a way to re-frame the discussion. With respect to the Dirac equation, frequency/energy, matter/antimatter and electric charge polarity are all interrelated and none can be dealt with independently of the others.

In this way we can think of electron and proton production as positive and negative electric charges with positive frequency—time—being produced together. That still leaves the question of what happens to the negative frequency—time—oscillations that we see in normal electron-positron and proton-antiproton pair production.

One important note is that while the quantum field is treated as a sea of matter-antimatter particle pairs such as quantum electron-positron pairs, a quantum electron-positron pair is equivalent to a pair of quantum electrons with opposite frequency and time arrow. So, in that sense, there is no antimatter.

The question of how the universe came to be a matter universe is then a question of how the electrons and protons are produced with positive frequency—time—instead of negative frequency—time, or vice versa. Simplistically, it is as if we could start with a quantum electron-positron and somehow get the positron to flip its frequency from negative to positive thus turning it into a proton. If such an event occurs it may be at instantaneously very high energy densities, perhaps at or beyond the Schwinger limit.

In order to solve the problem, we ultimately need to understand how electrons and protons are produced. This will require an excellent theory backed by experiment. Physicists must work on this problem as it is one of the most important in physics. We do find, however, that the arrow of time question is the same

as the preponderance of matter question and both questions ultimately have the same solution.

5. Origin of Quantum Frequencies

As stated previously, the origin of time is due to the frequencies of the quantum fluctuations of the quantum field. So, what is the origin of the quantum frequencies?

The author discussed this question in greater detail in a paper titled "Physical Constants as Properties of the van der Waals Torque of the Quantum Field."[2] In brief, among the van der Waals interactions produced by the quantum field is van der Waals torque. This torque resists all motion within the quantum field including the motion of the quantum fluctuations themselves.

The local torque of the quantum field regulates the oscillations of individual quantum fluctuations and simultaneously determines their energy, frequencies, and wavelengths. In this way the quantum field sets its own clock and the clocks of everything else. It also regulates the quantum fluctuation wavelengths and thus space's physical dimensions.

6. Conclusion

The above sections summarize the current state of knowledge of the origin of time, arrow of time, Dirac's energy and frequency, the matter/antimatter questions, and how those questions are all interrelated. Some of the author's observations are included.

Time originates with the frequencies of the quantum fluctuations of the quantum field, which exist in a continuum. The frequencies are determined by the local van der Waals torque of the quantum field so that the quantum field sets its own, and hence the universe's, clock rate. The universe's most fundamental unit of time, which we could call an electron-second, is the inverse of an electron's Compton frequency.

Dirac's negative energy should be thought of as negative frequency, which refers to propagation in a negative time direction in some presently unknown manner. Positive frequency equates to matter, while negative frequency equates to antimatter.

An antimatter observer in an antimatter universe would think they are matter in a matter universe. With respect to particles; time, matter and electric charge are all linked and likely can be described by a single theory and equation, which would essentially be an extended Dirac equation.

To definitively answer the question of how a net amount of matter—or antimatter—is produced instead of an equal mixture of matter and antimatter, we will need to first solve the problem of how electrons and protons are produced.

References

[1] Fleming, R., (2018), "Electrons and Protons Are Produced Together," GSJournal.net, August 14, 2018. http://gsjournal.net/Science-Journals/Research%20Papers/View/7414.

[2] Fleming, R., (2018), "Physical Constants as Properties of the van der Waals Torque of the Quantum Field," GSJournal.net, July 3, 2018. http://gsjournal.net/Science-Journals/Research%20Papers/View/7354.