ISSN: 2754-4753

Journal of Physics & Optics Sciences

Review Article

Reviewing the Role of Virtual Particles in the Vacuum

Barry Setterfield

Independent Researcher, Oregon, USA

ABSTRACT
Experimental evidence has established the existence of virtual particle pairs (VP) in the vacuum of space. The origin of these Virtual Particles is traced to the interacting waves of the Zero Point Energy (ZPE). The strength of the ZPE has been shown to increase with cosmic expansion, meaning the VP numbers would also increase simultaneously. Classical theory states that every time a charged particle undergoes an acceleration, it emits secondary radiation. The random waves of the ZPE impacting on all subatomic particles causes them to jitter (the 'zitterbewegung'). This jitter results in extremely rapid and continuous changes in direction for all subatomic particles and thus ongoing accelerations. As a consequence, all particles will emit secondary radiation which, in turn, boosts the ZPE strength locally around massive objects (along with a corresponding increase in VP numbers). The role played by the ZPE and associated Virtual Particles in the vacuum is then explored in relationship to the speed of light as well as some other effects that were predicted by relativity. These effects can now be shown to have an actual physical cause related to the ZPE and associated Virtual Particles.

***Corresponding author**
Barry Setterfield, Independent Researcher, Oregon, USA.

Received: November 14, 2023; **Accepted:** November 17, 2023; **Published:** November 27, 2023

Keywords: Zero Point Energy (ZPE), Virtual Particles (VP), SED Physics, Vacuum Properties, Atomic Behavior, Mass, Gravity, Speed of Light, Predictions of Relativity.

Introduction

In a recent paper, the energy intrinsic to the vacuum, the Zero Point Energy (ZPE), was discussed [1]. There are three items about the ZPE that are particularly relevant here. First, it was shown that the ZPE originated with cosmic expansion in a similar way that expansion of a rubber band, or the inflation of a balloon, imparted an energy to the fabric of the rubber band or balloon. Possible mechanisms were discussed in [1]. Second, it was shown that as universal expansion continued, the Zero Point Energy continued to build up in strength. This may be seen as similar to the increasing tensional energy residing in the fabric of a balloon as its inflation continues. This increasing ZPE strength with cosmic expansion has implications, some of which are discussed here.

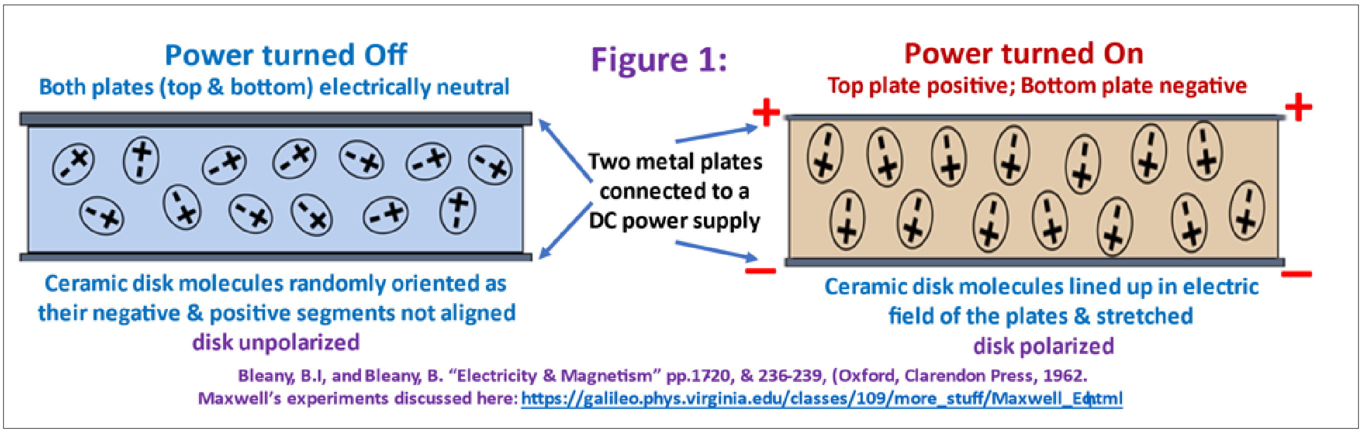
The third item was only mentioned briefly, namely that the Zero Point Energy controls the electromagnetic properties of the vacuum. Since atomic interactions are basically electromagnetic in character, this is of some importance. Indeed, one effect of the ZPE on atoms was discussed in some detail in [1]. Therefore, let us look in a little more detail at how the ZPE controls these properties of the vacuum and see where it leads. We begin with an experiment.

The Experiment-Part 1

Let us take two metal plates that have leads attached to a DC power supply along with all the appropriate measuring devices. We place a ceramic disk between the two plates. The power is then turned on and the voltage between the two plates is built up. As long as the voltage continues to build, the measuring devices show that a current is flowing between the two plates through the ceramic disk. But when the voltage has stabilized at any particular chosen point, the current is no longer measured as flowing through the ceramic disk. But since a current is not expected to flow through a ceramic disk at all, why was a current in evidence when the voltage was being ramped up?

Standard physics indicates that, as the voltage difference built up between the plates, the electric field between them affected the molecules in the ceramic disk. Each molecule in the disk has both a positively charged and a negatively charged segment. (The exact geometrical arrangement of these charges depends on the type of molecule we are dealing with.) As the applied voltage increased, the positive end of the molecule was attracted to the negatively charged plate, while the negatively charged part of the molecule was attracted to the positively charged plate. This increase in voltage also pulled on the molecules, which then stretched like a rubber band. When the voltage between the plates stopped increasing, the stretching ceased, and therefore the current stopped flowing.

Once the voltage difference between the plates is stable, the molecules have stretched to their maximum at that voltage and that is why the current is no longer flowing through the disk. The ceramic disk is then said to be polarized, because all the positive charges are aligned one way and the negative charges are aligned another (See Figure 1). The current in the ceramic disk, caused by the motion of these molecular charges over a short distance, was called a "displacement current" by Maxwell in 1861. The charges are simply displaced a short distance from their original positions.



The Experiment-Part 2

Let us now repeat the experiment without the ceramic disk, but in a vacuum from which all possible air and other atoms and particles are completely removed. It has been found from experiments that, once again, a displacement current flows between the two plates during voltage increases, and stops when the voltage stabilizes. However, the displacement current is not as strong as it was using the ceramic disk. Nevertheless, since a displacement current does indeed flow, Maxwell concluded that the vacuum must somehow have electric charges which can be polarized, just as the molecules in the ceramic disk were. Maxwell was uncertain as to what exactly constituted these vacuum charges,

Polarization can only occur if there are charged particles capable of being moved or re-oriented in an electric field. Yet we are working with what appears to be a true vacuum. The conclusion is that this vacuum must contain charged particles, capable of moving. But these charged particles are not associated with the air or any other matter, all of which had been expelled before we began. These charged particles, whatever they are, mean we have a "polarizable vacuum." The extent to which the vacuum "permits" itself to be polarized in an electric field is called the electric permittivity of free space. This permittivity is usually designated by the Greek letter epsilon written as ε.

It now must be pointed out that experiments show that any charge in motion – which is the definition of an electric current -- will also produce a circling magnetic field. This is what gives rise to the term "electro-magnetism." It is in this area that other experiments using magnetism have shown that the ceramic disk and the vacuum share a corresponding property. In the examples above, all the charged particles, whether in molecules or in the vacuum, were required to move in order to produce the displacement current and this current has its resulting magnetic field. The degree to which a magnetic field can permeate a substance is called its magnetic permeability. As a result, the presence of charged particles causes the vacuum of space itself to have a permeability as well as a permittivity. The magnetic permeability of space is usually designated by the Greek letter mu written μ.

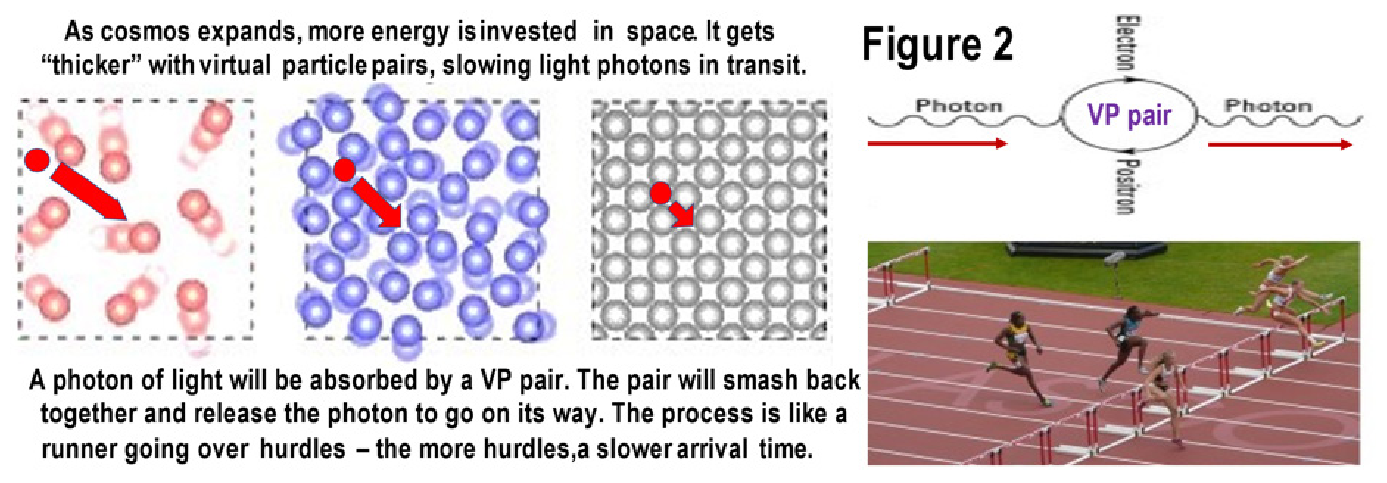
The Reason for the Polarizable Vacuum:

It then becomes important to find the origin of the "polarizable vacuum." This may be discerned in the context of a vacuum Zero Point Energy (ZPE) as discussed in reference [1]. Before going further, however, there are some important data about the ZPE that we may find helpful. The ZPE comprises electromagnetic waves of all wavelengths. It has many more short wavelengths than long ones. In physics, the shorter the wavelength means a greater frequency or number of waves passing per second. In fact, uniquely for the ZPE, the number of ZPE waves goes up with the cube of the frequency. This means that very small objects like atoms, around the size of the shorter wavelengths, are seriously jiggled by a huge number of waves hitting per second. In contrast, common items around our homes, like our chairs or tables or other furniture, approximate in size to some of the longer ZPE wavelengths. However, they are not jiggled because there are very few ZPE waves of that size. The ZPE exists as random (or stochastic) interacting waves. The study of these random waves and ZPE effects is known as SED physics or Stochastic Electro-Dynamics. So, every particle in the universe, from quarks (or even smaller) and continuing on upwards in size, is immersed in this sea of electromagnetic waves. Indeed, it has been shown that the ZPE sustains all atomic structures throughout the cosmos as derived and discussed in [1, 2].

In light of this background, let us now consider an everyday analogy. At the beach, we notice that, when ocean waves meet, they peak, crest and form whitecaps, foam or spray, which soon disappears and returns back to ocean waves. Similarly, when the energy waves of the ZPE in this 'cosmic ocean' meet, the concentration of energy forms particle pairs, positive and negative, just like ocean spray. This happens because energy and matter are inter-convertible as modern physics has shown. These particle pairs are called virtual particles because they quickly slam back together, annihilate, and return to energy. Because these virtual particle pairs (VP) are positively and negatively charged their movement produces magnetic fields. Examples of the VP are electron-positron pairs, proton-antiproton pairs, positive and negative pions, and so on. In fact, studies show that there is a whole range of virtual particles of at least 21 different types. Thus, along with the ZPE waves, they also control the electric & magnetic properties of the vacuum of space. Maxwell was not aware of this.

Vacuum Properties and the Speed of Light

This has some important consequences. For example, light is an electromagnetic phenomenon. This therefore means it is dependent on the ZPE. How this dependency results from the action of virtual particles are illustrated in Figure 2. Universal expansion means that more energy is invested in the fabric of space, which then gets "thicker" with virtual particle pairs.



While they exist, virtual particle pairs (VP pair in Figure 2), are able to absorb a traveling photon of light (red arrow). However, the moment they slam back together, that photon is re-emitted and goes on its way – until it hits another virtual particle, and the process repeats. So, the progress of light through space is like a runner going over hurdles. The more hurdles to jump, the longer is the run-time in the race. In a similar way, the more VP in its path, the longer it takes the photon of light to travel the distance through space from its emission to its point of final absorption such as an observer.

Something similar to this proposition first came from Robert Dicke in 1957 [3]. However, it was initially explored in detail in an article by Gerd Leuchs and his team in 2010. The authors stated in their Abstract that: "*By replacing the free space of classical physics with the quantum notion of the vacuum, we speculate that the values of the aforementioned constants [the permittivity and permeability of the vacuum] could arise from the polarization and magnetization of virtual pairs in the vacuum*" [4]. This bears the attendant implication that the speed of light is also affected.

Indeed, using a very similar mechanism in 2013, Marcel Urban and a team of astrophysicists from the University of Paris were able to reproduce the current speed of light from the interaction times of photons with virtual particles in the vacuum. They write specifically: "*When a real photon propagates in vacuum, it interacts with and is temporarily captured by an ephemeral [virtual particle] pair. As soon as the [virtual] pair disappears, it releases the photon to its initial energy and momentum state. The photon continues to propagate with an infinite bare velocity. Then the photon interacts again with another ephemeral pair and so on. The delay on the photon propagation produced by these successive interactions implies a renormalisation [change] of this bare velocity [from an infinite velocity] to a finite value. ... We then derive the photon velocity in vacuum by modeling its propagation as a series of interactions with these [particle] pairs*" [5]. It was pointed out (just below their equation (27)), that interaction times were independent of photon energies. If they were not, space would be a dispersive medium, bending different wavelengths by different amounts. They also state that for the vacuum permittivity and permeability, "*the electric charges and the number of species are the only important parameters*." The Urban team concluded that "*A consequence of this description is that the permittivity and permeability of free space and the vacuum speed of light are not fundamental constants, but observable parameters of the quantum vacuum: they can vary if the vacuum properties vary in space or time*" [5].

Outcome Summarized Plus an Additional Fact

The outcome of these facts for our study here is that any variation of ZPE strength will come with a similar variation in vacuum permittivity and permeability. Whatever direction this takes, there will be an inverse variation in the speed of light. (In physics, the speed of light is usually denoted by the letter "c"). The reasoning goes as follows: if there is an increase in the strength of the ZPE for any reason, this inevitably means that there will be more virtual particle pairs popping in and out of existence in a given volume of space. In turn, this means that there will be more interactions with light photons. As a result, it will take all light photons longer to get to their destination, as in Figure 2, and detailed in references [6-8]. It was pointed out that Planck's second paper of 1911 revealed that Planck's constant, "h," was a measure of ZPE strength [1]. It follows, then, that lightspeed, "c," is inversely proportional to "h." This means that the quantity "hc" will be invariant throughout the cosmos, and has proven to be so in astronomical observations, as outlined in [6-8]. The implication is that lightspeed was considerably higher in the early universe when the ZPE strength was just starting to build up with the initial comic expansion and very few virtual particles existed.

This implication alone may solve or at least change some astronomical difficulties such as the so-called "horizon problem." The horizon problem refers to the idea that if the speed of light has been constant through time, and therefore always at the speed it is now, there is no way that one part of the early universe could have been in contact with another part. And yet, the cosmic microwave background radiation (CMBR) shows that everything was the same temperature initially. That means that, somehow, one part of the universe had to be in contact with every other part initially. Though other mechanisms have been proposed, this problem is potentially overcome if the speed of light in the early universe was significantly faster than it is now. As Marcel Urban indicted, the speed of the photons themselves was close to infinite between interactions with virtual particles [5]. These particles thus impeded the progress of these photons as they traveled, and the present virtual particle density (due to the current ZPE strength) causes the current speed for light. Therefore, if there were very few virtual particles initially, lightspeed would be extremely high, and all parts of the cosmos could be in contact. Physicists Albrecht, Magueijo and Barrow have confirmed this is possible [9, 10].

Classical electrodynamics requires that a charged particle, such as an electron or proton, emits a secondary or recoil radiation when its direction of motion changes. This has been confirmed experimentally. Physicists researching the ZPE have noted that all matter is made up of charged particles. These particles are being battered by the ZPE from different directions. As a result, all particles are emitting secondary radiation with the ongoing ZPE impacts [11]. It has also been pointed out that the Compton frequency of an electron, 1.23 x 10^20, is the number of hits per second from ZPE impacts. Each hit changes the direction of movement of the electron, which results in secondary radiation being emitted. This means that, around a massive body, such as the sun or the earth, there is a local increase in the strength of the ZPE due to all the secondary radiation being emitted by the "jitter" of the particles making up that body. That "jitter" has the scientific name of 'zitterbewegung.' As a result, the more massive the body, the more particles are involved in the 'jitter' and so the greater the local increase in ZPE strength. The vacuum of space, as described by these ZPE concepts, can therefore be considered an optical medium, transmitting light. The density of this optical medium increases towards any massive object [12-14]. As light photons enter this locally denser medium, they are slowed down and refraction occurs. with the results as detailed in [15].

ZPE Effects and Relativity Compared (1):
With the foregoing background information, we are now in a position to make an assessment of an important statement by Sir Arthur Eddington, a friend and strong supporter of Albert Einstein. In 1920, Eddington pointed out that exactly the same effect that the complicated mathematics of General Relativity uses to propose the bending of light in a gravitational field, can also be obtained much more simply by the effects of an equivalent optical medium [15]. Eddington writes:
"*Light moves more slowly in a material medium than in a vacuum, the velocity being inversely proportional to the refractive index of the medium… We can thus imitate the [GR] gravitational effect on light precisely, if we imagine the space round the Sun filed with a refracting medium which gives the appropriate velocity of light. … Any problem on the paths of rays near the Sun can now be solved by the methods of geometrical optics applied to the equivalent refracting medium*" [16].

Since then, others have discussed this proposal. De Felice mentioned nine authors who have looked at this similarity between gravitation and an optical medium [17]. He makes the interesting point in his Abstract that when this is done "…*we find that the [mathematical] language of classical optics for the 'equivalent medium' is as suitable as that of Riemannian geometry*" since exactly the same result is obtained [17]. Indeed, the combined effect of the ZPE plus the secondary fields near massive bodies (induced by the "jiggling" of sub-atomic particles), have been shown to be the precise optical medium required by Eddington [15]. This enhanced ZPE medium around massive objects is electromagnetic in origin. Therefore, it can be shown that the strength of these electromagnetic fields is proportional to the inverse square of their distance from the origin. This is exactly the same as a gravitational field. In addition, their potential falls off inversely as the distance from the massive body, again mimicking the behavior of the gravitational potential [15]. We therefore have a real and physical mechanism as to why a light ray is deviated as it passes near the sun or some other massive body. This physical mechanism gives exactly the same results as Einstein's relativity, but uses simple mathematics to calculate those results. This is in direct contrast with the purely mathematical modelling of relativity which uses complicated Riemannian geometry.

ZPE Effects and Relativity Compared (2)
The bending and slowing of light in the gravitational field of massive bodies was only one of several major predictions made by General Relativity. Einstein also proposed that the rate of ticking of atomic clocks would be slowed in gravitational fields. This GR prediction also has a natural explanation using the ZPE mechanism. The "gravitational field" in which these atomic clocks are immersed comes from the enhanced ZPE that originates with the oscillating charges making up all matter. The more charges there are to oscillate, the more secondary radiation will be emitted, and hence the greater the energy density of the ZPE in that vicinity. This local increase in the energy density will slow atomic processes and cause a drop in the orbital frequency of subatomic particles as shown in [1]. This slowing occurs because most atomic processes are electromagnetic in character and so will be inhibited as the ZPE strength increases. Consequently, atomic clocks will all slow around massive objects. Indeed, the closer to the massive body, the slower the atomic clock will run. This is examined in more detail and shown to be in accord with experimental data [15, 18].

ZPE Effects and Relativity Compared (3)
The planet Mercury traces out an elliptical path around the Sun. The closest point of that ellipse to the Sun is called the perihelion. However, Mercury does not trace exactly the same path each time. Rather the path swings around over time. When the path is plotted out, it can be seen that the perihelion position rotates around the Sun. Mercury's orbit therefore looks something like the situation shown in Figure 3.

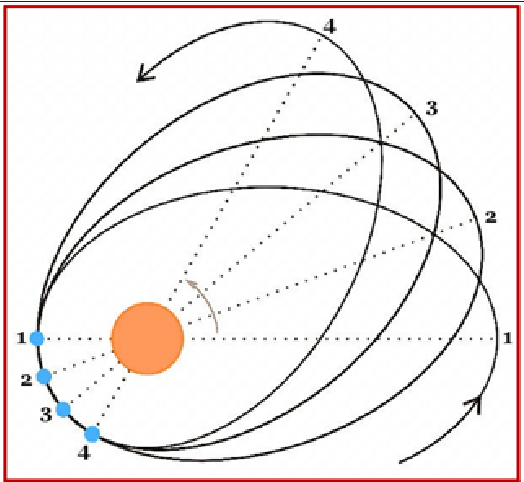


Figure 3: The advance of Mercury's perihelion.

This result can be explained on a heuristic basis from a suggestion first made in 1999 that appeared in a collection of symposium papers published in 2002 [19]. The symposium noted that if, perchance, the planets were immersed in a medium that increased its density towards the Sun, then:

"*The elliptical motion of orbiting bodies is slowed most by [the medium] at perihelion where the medium is densest, and slowed least at aphelion, where [the medium] is sparsest. This velocity imbalance (relatively slower at perihelion, relatively faster at aphelion) rotates the ellipse forward, which is what an advance of perihelion means*" [19].

This is definitely in line with SED physics, which has an increased energy density of the ZPE near the Sun or any massive body. However, it may be wondered how a planet in orbit could experience an imbalance of the Newtonian velocity as a result of changes in the strength of the ZPE. Since the ZPE strength is greater near the Sun, then so, too, are the number of virtual particle pairs in the vacuum at any given instant. In other words, an increase in ZPE strength means that the vacuum becomes "thicker" with virtual particle pairs. In the case under consideration here, the closer we get to the Sun, the greater the number of virtual particles in the vacuum at any instant.

From ordinary Newtonian considerations, Mercury in its elliptical orbit moves very fast when close to the Sun, then significantly slower when farther away. Just at the time when it is going at its maximum speed, Mercury is also entering and traveling through the area of greatest ZPE strength. This means it will encounter a much thicker cloud of virtual particles as it moves at high speed near the Sun, and then significantly fewer when farther away. As Mercury moves ballistically through a thick cloud of virtual particles when closest to the Sun, this generates a resistance. This occurs because virtual particles are of equivalent size to the sub-atomic particles making up all matter.

This "vacuum drag" has been noted as being open to observation on small particles. The analysis pointed out that, even though the bombardment comes equally from all sides, the retarding force is greater when a virtual particle hits in a direction opposite to the motion of the body in question. The force is much less if the virtual particle has to "catch up" with the object instead of hitting head-on [20]. This process produces a retarding effect at the atomic level and an imbalance is induced in the Newtonian velocity which rotates the perihelion of the orbit ellipse in a forward direction. This is treated mathematically and quantified in reference [21]. The result, in agreement with observation, comes from a real physical slowing factor whose effects can be derived exactly without any other effects needing to be considered. By contrast, Einstein had to consider the combined action of four different effects to get a result matching observation. Some of those effects had to be added, some subtracted to achieve the desired outcome. However, it appears that the predictions of General Relativity can be reproduced more simply by considering a scenario based on the action of the Zero Point Energy. (A more detailed discussion can be found in references [15, 21].

An Historical Summary

Because there was no real option available, consensus science followed the path taken in the early 20th century concerning relativity. It was only after 1962, when de Broglie pointed out that science may have taken a wrong turn in the 1920's, that the idea of a real physical ZPE and its effects was examined seriously [22]. From 1962 until 1998 the theoretical and practical base was being built [1]. The full proof of the ZPE's existence was only experimentally verified to within 1% in 1998 [23]. It was in 2010 that it was proven experimentally that the impacting waves of the ZPE really were jiggling every electron at the Compton frequency of 1.23 x 10^20 hits per second [24]. Finally, it was only in 2013 that Marcel Urban and his team proved beyond doubt that the speed of light was determined by the interaction of light photons with the virtual particle pairs of the vacuum that resulted from the ZPE [5]. The collective significance of these theoretical concepts and their experimental proof has understandably been slow in filtering down to the general scientific community. For that reason, the veracity of the above conclusions may seem iconoclastic to some, but the evidence has been slowly building for over 60 years.

Some Additional Evidence

First, on 20th May, 1964, using the Bell Labs Horn Antenna at Holmdale, New Jersey, radio-astronomers Arno Penzias and Robert Wilson discovered the Cosmic Microwave Background Radiation (CMB). This CMB is sometimes called the "echo of the Big Bang." It records the moment when the cosmos had expanded sufficiently to became cool enough for neutral atoms to form so that light shone out of the plasma fog. Though there are many items of interest to explore from this event, there is one in particular which concerns us here. Because of the ongoing expansion of the universe, the original high temperature of the cooling plasma, recorded by the CMB, has now dropped to 2.726 degrees Kelvin (that is 2.726 degrees above absolute zero). Examination of this CMB signal shows a high degree of uniformity across the whole sky, with variations only being of the order of 1 part in 100,000.

Because of this uniformity, this "isotropic bath of radiation" (as it is often called) undergoes a Doppler shift with the motion of any observer. Thus, it appears slightly warmer in the direction of travel and slightly cooler in the opposite direction [25].

This cosmic microwave background radiation allows us to determine an absolute frame of reference for the direction and speed of any object anywhere in the universe. For instance, the speed and direction of the Sun and solar system in their motion around our galaxy has been recorded as 369.0 +/- 2.5 km/s in the direction of the constellation of Leo [26]. The speed of our galaxy against the CMB rest frame is 552.2 +/- 5.5 km/s [27]. Likewise, a speed of 627 +/- 22 km/s has been recorded for our Local Group of galaxies as a whole towards the Virgo supercluster of galaxies [27]. These figures have been confirmed by other studies.

Einstein did not have these data available when he published his theory of Special Relativity, so he built his equations on the postulate was that there was no absolute reference frame for speed or direction anywhere in the universe. Martin Harwit in discussing these data has this to say about that problematic issue:
"*Current observations indicate that the universe is bathed by an isotropic bath of microwave radiation. It is interesting that the presence of such a radiation field should allow us to determine an absolute reference frame on the basis of a local measurement."*
Harwit then goes on to salvage what he can for relativity by saying:
"…the establishment of an absolute rest frame would emphasize the fact that special relativity is really only meant to deal with small-scale phenomena and that phenomena on larger scales allow us to determine a preferred frame of reference in which cosmic processes look isotropic" [25]. In other words, Harwit is suggesting that relativity may only be correct when dealing with atomic-scale phenomena rather than on a larger scale.
There is an additional matter which must also be considered in this context.

More Evidence

Well before the 20th century papers of Planck, Einstein and de Broglie, physicists were measuring and discussing the speed of light. The changes they were measuring were being discussed and documented in the scientific literature starting in the 18th & 19th centuries. The data indicating this progressive and systematic change were the results of many hundreds of individual experiments by more than a dozen methods over many years. The complete list of data, documentation, initial statistical treatment, and accompanying graphs can be found in references [6, 28]. This evidence becomes more pertinent in view of the research of Marcel Urban and his team [5]. The Marcel team quantified the inverse dependence of the speed of light on the number of virtual particles in a given volume of the vacuum. Additional relevance is added to their research by the evidence that the ZPE strength was expected to increase as universal expansion went on [1]. In support of this possibility, here are some samples of the discussion about the way the measured speed of light has behaved over time.

In 1886, Simon Newcomb, Professor at US Naval Observatory, Washington, reluctantly concluded that the values of lightspeed, c, obtained around 1740 were in agreement with each other, but were about 1% higher than in his own time [29]. This is detailed in Figure 4 on the left panel. As Newcomb noted, the data set in each individual time-slot were in agreement with each other. However, when the two time-slots were compared, there had been a drop in the measured value of c of around 650 km/s. In 1941, Raymond T. Birge, Professor of Physics, Uni. California, Berkeley, made a parallel statement while writing about the c values obtained by Newcomb, Michelson and others around 1880. Birge conceded that "…*these older results are entirely consistent among themselves, but their average is nearly 100 km/s greater than that given by the eight more recent results*" [30]. The fact that both these scientists preferred the concept that the value of c was constant, as did many others, makes their admission of declining experimental values significant.

This is illustrated further by the 67 determinations by the Aberration Method. When they are split into 50-year segments, and the mean c-value in each segment is taken, the difference of that mean from the current value for the speed of light can be noted as in Figure 4 (right-hand panel). This shows that, the further back in time we go, the higher the mean value of c and the greater the difference when compared with c-now, the current accepted value of lightspeed, namely 299,792.458 km/s.

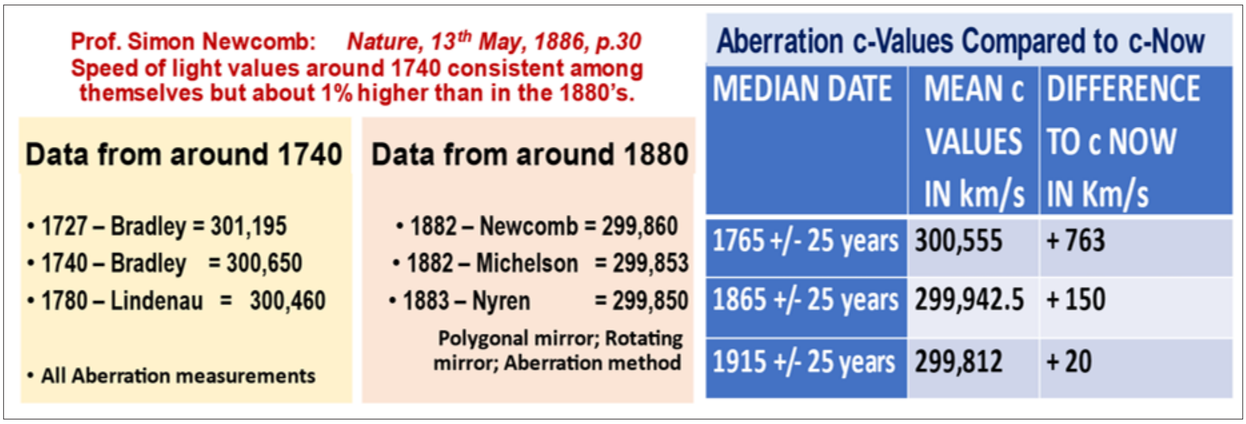


Figure 4: Comparison of Time-Grouped "c" Data Associated with Comments by Physicists

In 1927, M.E.J. Gheury de Bray did an initial analysis of the speed of light data [31]. After four new determinations by April of 1931, he wrote: "*If the velocity of light is constant, how is it that, INVARIABLY, new determinations give values which are lower than the last one obtained….There are twenty-two coincidences in favor of a decrease in the velocity of light, while there is not a single one against it*" (his emphasis retained) [32]. Even though the difference was only about 1.5% or 1500 km/s in several hundred years, the trend was systematic and one-sidedly downwards. A thorough analysis revealed it was statistically significant above the 95% confidence level [33]. Some had suggested that the declining values were the result of improvement in equipment or techniques or different observers.

However, the aberration data from Pulkovo Observatory, Russia, negates that suggestion. For over 100 years, the same equipment was used, along with many of the same observers over their lifetimes. The plotted data show the systematic decline, as can be seen from Figure 5 (left).

When all the data were collected, the experiments examined, and discussions considered, there were 163 determinations of lightspeed by 16 methods over a period of 300 years. Each determination resulted from hundreds of observations; in the case of the aberration data, it often ran into thousands of observations. When the best data, namely those with errors of less than 0.1%, were plotted, the result was the right-hand graph in Figure 5.

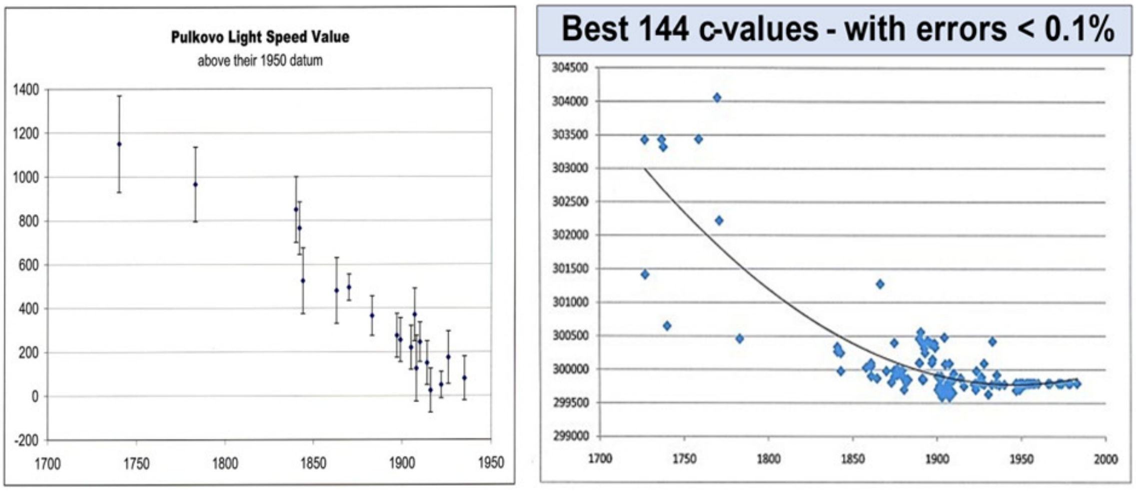


Figure 5: (Left) Light-Speed Determined by The Aberration Method at Pulkovo Observatory. (Right) c-values with Errors Less than 0.1%. Further Analysis and Explanations can be found in References [7] and [28].

Birge's Argument Against c- variation

Professor R.T. Birge, physics professor, University of California, Berkeley, issued updated values for these important quantities in physics. For this reason, he was called the "Keeper of the Constants." His up-dating was based on analyses of all the incoming experimental data. He was thus obviously aware of all of them. However, in 1934, when he was asked the reason for his rejection any variation in lightspeed, he responded publicly in the science journal Nature. First of all, he pointed out that wavelengths of light as well as length standards had been proven by experiment to be unchanged over the time when lightspeed had been measured as varying. He then gave his reason for not accepting c variation because "… *if the value of c...is actually changing with time, but the value of (wavelength) in terms of the standard meter shows no corresponding change, then it necessarily follows that the value of every atomic frequency...must be changing. Such a variation is obviously most improbable*...." [34].

What Birge is saying here is an important data conclusion. He says that, since wavelengths of light are not changing as the speed changes, this can only mean that the frequency of light changes by the same proportion that the speed changes as light travels through space. The train analogy in Figure 6 shows that this really is a quite reasonable proposition and not at all as improbable as Birge thought.

Figure 6: The Train Analogy to Illustrate Birge's Concern from Experimental Data, that Leads to an Important Conclusion

The problem for Birge stems from the fact that light is emitted from atoms as an electron drops from an outer orbit to an inner orbit. The key factor here is that the frequency of the emitted light does indeed depend on atomic frequencies. For example, when an electron drops from the 2nd to the 1st Bohr orbit in hydrogen, the light emitted has a frequency identical to the frequency of the revolution of the electron in that orbit [35]. So, the speed of light and atomic frequencies is indeed linked, just as Birge claimed in his objection. Therefore, if the speed of light was higher in the past, then the electron went around in its orbit more quickly. To Birge, this was a problem as it meant that atomic phenomena were somehow linked with light-speed – and he had no known common cause.

The cause that Birge had needed to convince him was not discovered until 1987 when research showed that the ZPE sustains all atomic orbits throughout the cosmos [36]. This was independent of any discussion about lightspeed, but Birge did not have this data or the theoretical backup to consider. However, it all follows from the way the ZPE controls the electric and magnetic properties of the vacuum and hence electromagnetic interactions in atoms. The speed of light, and atomic behavior may both be considered to be different children of the same ZPE parent. What was a problem to Birge, turns out to be what we see actually occurring in atoms as we look farther and farther out into space [1].

Gravity, Mass and Inertia

A Suggestion About Gravity

Some final suggestions might also be worth considering. We have noted that all sub-atomic particles carry an intrinsic charge. The mere presence of the charge on these particles polarizes the vacuum around them. Thus, a negative electron becomes surrounded by a layer of positively charged virtual particles which in turn is surrounded by a layer of negatively charged virtual particles, and so on out into the vacuum. This vacuum polarization acts to attract other virtual particles which may be nearby. The sign of the charge initially attracted does not matter; it only affects the phase of the interactions. If the virtual particle-pair is considered to be a single entity, then that pair has a positive end and a negative end. Thus, one end of the single particle-pair entity will be attracted to the charge of opposite sign. However, this is envisaged, there is a resulting re-orientation of virtual particle pairs in the vacuum; the vacuum is polarized by the very presence of the charge on subatomic matter.

This vacuum polarization acts to attract sub-atomic particles, protons, electrons, or quarks which may be nearby. This net attractive force between sub-atomic particles caused by vacuum polarization has been shown by SED physicists to be quantitatively identical to gravity. So, the larger the collection of particles, the stronger is the resulting attraction we call gravity. Haisch concluded this explanation for the origin of gravity when he said, "*This might explain why gravity is so weak. One mass does not pull directly on another mass but only through the intermediary of the [charged virtual particles that make up the] vacuum*" [37].

A Suggestion about Mass

It has already been shown that the random, ultra-relativistic, "jitter" imparted by the impacting waves of the ZPE, gives each charged, massless, point particle (that makes up all matter), a kinetic energy [1, 18]. This means that it is the ZPE "jitter" that is imparting the rest-mass to all subatomic particles. This has been quantified and shown to be in agreement with the data from experiments in [37-39]. Strict analysis has shown that, in a situation with an increasing ZPE strength, "h," the masses of all atomic particles increase in proportion to "h^2." Since we have pointed out above that "hc" is a constant, then it follows that mc^2 is also a constant, and energy is conserved in this process. This, too, has been quantified in and experimentally verified by the data and graphs in [7,21,40].

We can go further. ZPE physicists have noted that different particles will have different resonant frequencies because of their different internal structure. As a result, they will have different masses. This occurs because a particle's natural resonant frequency is also the frequency of the ZPE waves which have the most effect in causing the jitter for that particle. There are many more ZPE waves with a short wavelength. Therefore, the higher the resonant frequency, the more it will be jittered by the ZPE. It is the kinetic energy from this jitter which manifests as mass.

SED physicists have written: "*[ZPE] Photons in the quantum vacuum with the same frequency as [a particle's] jitter are much more likely to bounce off that particle... Higher resonant frequencies [for a particle] ... probably mean a greater mass, as there are more high frequency vacuum photons [of the ZPE] to bounce off*" [41].

A Suggestion About Inertia

It was pointed out in 1994 that the approach using the ZPE may also account for inertia. Haisch, Rueda, and Puthoff have considered what happens when any sub-atomic particle, for example an electron, is accelerated through the ZPE fields of the vacuum. They point out that the particle will experience a pressure, a retarding force, from those ambient fields that it is running into. This retarding force or pressure was shown to be proportional to the particle's acceleration [41].

Outcome of Discussion

The ultimate outcome is that the presence of virtual particle pairs (VP) in the vacuum as a result of the Zero Point Energy allows a simple explanation of a number of phenomena. This is due to the physical effects of these VP, coupled with their increasing numbers universally, since cosmic expansion increases ZPE strength. ZPE strength, and hence the numbers of VP, also increases locally around massive objects due to the secondary radiation emitted by every sub-atomic particle undergoing its "jitter motion" (often called the '*zitterbewegung*'). Using this mechanism, the ZPE and its accompanying virtual particles can account for many effects that relativity has predicted, and some which it suggested were improbable, such as changing lightspeed. In so doing, this ZPE approach uses simple mathematics rather than using complicated geometry and the esoteric mathematics of relativity. It would therefore seem that this line of enquiry may prove useful to follow as a possible alternative approach to explaining relativistic phenomena as the two key postulates on which relativity is based (a constant lightspeed through all time, and no absolute reference frame anywhere in the universe) have been called into question.

References

1. Setterfield B (2023) Reviewing Redshifts and the Zero Point Energy, Journal of Physics and Optic Sciences 5: 1-9.
2. Puthoff HE (1987) Ground state of hydrogen as a zero-point-fluctuation-determined state. Physical Review D 35: 3266.
3. Dicke RH (1957) Gravitation without a Principle of Equivalence. Rev Mod Phys 29: 363.
4. Leuchs G, Villar AS, Sanchez-Soto LL (2010) The quantum vacuum at the foundations of classical electrodynamics. Appl Phys B 100: 9.
5. Urban M, Couchot F, Sarazin X, Djannati-Atai A (2013) The Quantum Vacuum as the Origin for the Speed of Light, The European Physical Journal D 67: 58.
6. Norman T, Setterfield B (1987) Invited Research Report, SRI International and Flinders University, The Atomic Constants, Light and Time, prepared for Dolphin LT 28. https://www.ldolphin.org/setterfield/report.html
7. Setterfield B (2012) Zero Point Energy, Light and Time, Proceedings of the NPA 9: 549-563.
8. Maryland US (2013) "Cosmology and the Zero Point Energy," Volk, G, Editor, NPA Monograph Series No. 1 for Natural Philosophy Alliance 20th Annual Conference 53-55.
9. Albrecht A, Magueijo J (1999) Time varying speed of light as a solution to cosmological puzzles. Physical Review D 59: 043516.
10. Barrow JD (1999) Cosmologies with varying light speed. Physical Review D 59: 043515.
11. Chown M (2001) "Mass Medium" interviewing Puthoff H, Haisch B, Rueda A. New Scientist 22-25.
12. Haisch B, Rueda A, Puthoff HE (1994) A first glimpse of a postmodern physics, in which mass, inertia and gravity arise from underlying electromagnetic processes. The Sciences

34: 26-31.
13. Puthoff HE (1989) Gravity as a zero-point-fluctuation force. Physical Review A 39: 2333-2342.
14. Haisch B, Rueda A, Puthoff HE (1997) Physics of the Zero-Point Field: Implications for Inertia, Gravitation and Mass. Speculations in Science and Technology 20: 99-114.
15. Setterfield B (2012) Zero Point Energy and Relativity. Proceedings of the NPA 9: 528-548. 19th Annual Conference of the Natural Philosophy Alliance, Albuquerque, New Mexico 25th – 28th July 2012.
16. Eddington A (1920) Space, Time and Gravitation. Cambridge University Press reprint 1987: 109.
17. de Felice F (1971) On the gravitational field acting as an optical medium. General Relativity and Gravitation 2: 347-357.
18. Maryland US (2013) "Cosmology and the Zero Point Energy," Volk, G. Editor, NPA Monograph Series No. 1 for Natural Philosophy Alliance 20th Annual Conference: 138-160.
19. Edwards MR (2002) Editor, Pushing Gravity. Montreal: Apeiron 99.
20. Science Editor (2011) New Scientist. Issue 2799: 12.
21. Maryland US (2013) "Cosmology and the Zero Point Energy," Volk, G. Editor, NPA Monograph Series No. 1 for Natural Philosophy Alliance 20th Annual Conference 258-297.
22. De Broglie L (1962) New Perspectives in Physics, (Basic Books Publishing Company). https://www.amazon.in/New-Perspectives-Physics-Broglie/dp/0465050611
23. Mohideen U, Roy A (1998) "Precision Measurement of the Casimir Force," Physical Review Letters 81: 4549-4552.
24. Gerritsma R, Kirchmair G, Zahringer F (2010) "Quantum simulation…" Nature 463: 68. https://core.ac.uk/download/pdf/52683761.pdf
25. Harwit M (1988) Astrophysical Concepts, 2nd Edition (Springer-Verlag, New York) 178-179.
26. Lineweaver CH, Tenorio L, Smoot GF, Keegstra P, Banday AJ, et al. (1996) "The Dipole Observed in the COBE Data…". Astrophysical Journal 470: 38-42.
27. Kogut A, Lineweaver C, Smoot GF, Bennett CL, Banday A, et al. (1993) "Dipole anisotropy in the COBE differential microwave radiometers first-year sky maps". The Astrophysical Journal 419: 1-6.
28. Maryland US (2013) "Cosmology and the Zero Point Energy," Volk, G. Editor, NPA Monograph Series No. 1 for Natural Philosophy Alliance 20th Annual Conference 72-137.
29. Newcomb S (1886) The Velocity of Light. Nature 29-32.
30. Birge RT (1941) The General Physical Constants, Reports on Progress in Physics 8: 90-101.
31. Gheury de Bray MEJ (1927) The Velocity of Light. Nature 120: 602-604.
32. Gheury de Bray MEJ (1931) Published Values of the Velocity of Light. Nature 127: 522 & 892.
33. Montgomery A, Dolphin L (1993) Is the Velocity of Light Constant in Time? Galilean Electrodynamics 4: 93.
34. Birge RT (1934) The Velocity of Light. Nature 134: 771-772.
35. French AP (1959) Principles of Modern Physics (Wiley, New York) 113-114.
36. Puthoff HE (1987) The Ground State of Hydrogen as a ZPF Determined State. Physical Review D 35: 3266.
37. Chown M (2001) Quoting Puthoff, H.E, Haisch, B., Rueda, A in "Mass Medium," New Scientist 22-25.
38. Puthoff HE (1989) Gravity as a zero-point-fluctuation force. Physical Review A 39: 2333-2342.
39. Haisch B, Rueda A, Puthoff HE (1994) Inertia as a zero-point-field Lorentz force. Physical Review A 49: 678-694.
40. Norman T, Setterfield B (1987) Invited Research Report, SRI International and Flinders University, The Atomic Constants, Light and Time, prepared for Dolphin LT 31. https://www.ldolphin.org/setterfield/report.html
41. Haisch B Rueda, A Puthoff HE (1994) Inertia as a zero-point-field Lorentz force, Physical Review A 49: 678-694.