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Photogenesis: How Motion Becomes Matter

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Abstract

Photodynamics refers to the dynamics of particles, like the photon, that have a rest mass and travel at the speed of light. Recently we derived an energy-momentum theorem which provides the dynamics of such particles. In this paper we derive the same theorem from a slightly different point of view which better illustrates the connection between kinematics and dynamics. We use the photon, and its associated photokinetics to reveal how its rest mass is created. We reveal the same process at work in Quantum Mechanics. We then discuss the process of Photogenesis which we believe, at the fundamental level, is used to create matter, and argue that it has universal applicability.

Keywords: Kinematics; Dynamics; Nature of photon's rest mass; Role of c and $\hbar$ in mass creation; Photokinetics; Photogenesis

Introduction

The long standing mystery of the photon's rest mass was resolved in our paper on photodynamics when we examined the photon in its rest frame, that is, the frame in which its translational speed is reduced to zero. We found that in its rest frame the photon has residual motion consisting of a circle perpendicular to the flight axis which rotates, right or left, at the speed of light with frequency ω_0. When ω_0 becomes zero, the rest mass of the photon also becomes zero, and the photon disappears. But a number of questions remain. Yes, the photon has a non-zero rest mass, but what is its nature, and where does it come from? In this paper we examine the origin of the photon's rest mass and the connection of mass to motion in general. We introduce the concept of Photogenesis by which massive objects are created.

Kinematics

Kinematics is the essence of being. A body is not simply kinematics, but without it, it cannot exist This is a rather strong assertion which we intend to defend.

All particles or bodies, in order to exist, must exist in space-time. The motion of particles in space-time must be able to be described by and must obey a relativistic kinematics. Thus all bodies have a kinematic content. The best way we know to demonstrate this is to recall how we obtained energy-momentum theorems of massive particles in a previous paper. In our paper on photodynamics [1] we derived the energy-momentum theorems of both type 1 and type 2 particles by starting with a kinematic identity based on the definition of the Lorentz factor. Recall that type 1 particles can travel at the speed of light, while type 2 particles cannot. Since the Universe consists of only these two types of particles, this confirms that all bodies have kinematic content. For type 2 particles we started with the identity in the form

$$\gamma_u^2\left(1-\frac{\overline{u}^2}{c^2}\right)=1. \tag{1}$$

We then multiplied Eq. (1) by the constant $E_0^2 = m_0^2c^4$ to get the energy-momentum theorem

$$E_u^2 - c^2\overline{P}_u^2 = E_0^2 \tag{2}$$

where,

$$E_u = m_u c^2 = m_0\gamma_u c^2,\ \overline{P}_u = m_0\overline{u}\gamma_u,\ E_0 = m_0c^2. \tag{3}$$

Eq.(2) is the well known Einstein energy-momentum theorem which applies to bodies that can't travel at the speed of light. Notice the complete generality of the method. The mass m_0 in the above equations is not specified at all, and could be the mass of any body, big or small, as long as it is type 2.

For type 1 particles, like the photon, that have non-zero rest mass and travel at the speed of light, we derived a new energy-momentum theorem starting with the same identity in the form

$$\frac{1}{\gamma_u^2}+\frac{\overline{u}^2}{c^2}=1. \tag{4}$$

We then multiplied Eq. (4) by the constant $e_0^2 = m_0^2c^4$ to get

$$e_u^2 + c^2\overline{p}_u^2 = e_0^2, \tag{5}$$

where

$$e_u = \frac{e_0}{\gamma_u},\quad \overline{p}_u = m_0\overline{u},\quad e_0 = m_0c^2. \tag{6}$$

The combination of Eq. (5) and the associated definitions in Eq. (6) form the basis of a new dynamics applicable to photons, and other type 1 particles, which we called Photodynamics. Together with the photon's angular momentum, $\hbar$, we then showed that the energy of the photon, in its rest frame, is

$$e_0 = \hbar\omega_0 = m_0c^2. \tag{7}$$

For the purposes of this paper we would like to emphasize that what made photodynamics possible was the relativistic kinematics on which it was built. To this end, we will now derive photodynamics without using mass explicitly to provide dynamic content. We start with Eq. (4), and multiply it by $e_0^2 = \hbar^2\omega_0^2$, then divide by $\hbar^2$ to get

$$\omega_u^2 + c^2\overline{k}_u^2 = \omega_0^2, \tag{8}$$

where

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$$\omega_u = \frac{\omega_0}{\gamma_u},\ \bar{k}_u = \frac{\omega_0 \bar{u}}{c^2}. \tag{9}$$

Taking the photon's flight axis to be the z axis, we separate Eq. (8) into two parts

$$\omega_z^2 + c^2 k_z^2 = \omega_0^2,\ \omega_\perp^2 + c^2 \bar{k}_\perp^2 = \omega_0^2, \tag{10}$$

where,

$$\omega_\perp = \omega_0 / \gamma_\perp,\ \gamma_\perp = 1/\sqrt{1 - u_\perp^2/c^2},\ u_\perp^2 = u_x^2 + u_y^2,\ k_\perp = \omega_0 u_\perp / c^2. \tag{11}$$

Let ***R*** be the photon's rest frame where $u_z = 0$. When the photon is at rest in its flight path, $k_z = 0$ and $\omega_z = \omega_0$, its rest frequency. Even at rest we notice that $\omega_z = \omega_0$ is not zero. In its rest frame, there is residual motion, not along the flight axis, but in the *x,y* plane perpendicular to it. The speed $u_\perp = \sqrt{u_x^2 + u_y^2}$ is a velocity associated with the motion of the photon in a plane perpendicular to its flight axis. We take this motion to be the rotation of a circle at the speed of light since this will provide the photon's angular momentum, as we will see, and *c* and $\hbar$, excluding gravity, are the only universal constants available to construct fundamental particles. Eq. (11) then gives

$$c = \frac{\omega_0}{k_\perp} = \rho_0 \omega_0, \tag{12}$$

where $\frac{1}{k_\perp}$ is seen to be the radius of the circle determined by *c* and ω.

We know that every photon must have an angular momentum $\pm\hbar$ along its direction of flight. This angular momentum is given by

$$L_z = h\left(\bar{r} \times \bar{k}\right)_z = \pm h\left(\rho_0 \frac{1}{\rho_0}\right) = \pm h \cdot \tag{13}$$

So even in the photon's rest frame, there is motion providing both the required angular momentum $\pm\hbar$, and ω_0, which when multiplied by $\hbar$ provides the photon's rest energy.

Mass, Materialization, Genesis

Notice that in the above formulation we have not multiplied Eq. (4) by $m_0^2c^4$. In fact we have not introduced m_0 at all, just the rest frequency, ω_0 which for a photon would seem to be more appropriate. But, we don't have a photon yet. Eq. (8) just contains the relativistic kinematics of the photon, but no dynamic properties. We must multiply Eq. (8) by $\hbar^2$ and Eq. (9) by $\hbar$ before we can create the dynamic energy-momentum theorem, Eq. (5), and the dynamic variables

$$e_u = h\omega_u,\ \bar{p}_u = h\bar{k}_u,\ e_0 = h\omega_0. \tag{14}$$

Now we can take a time derivative of eqn. (5) to get

$$\frac{de_u}{dt} = -\gamma_u \bar{u}.\bar{f}_u, \tag{15}$$

where

$$\bar{f}_u = \frac{d\bar{p}_u}{dt}. \tag{16}$$

Eqns. (14)-(16) then allow us to use energy minimization to provide the photodynamic mechanism which drives the photon to the speed of light. Kinematics by itself cannot create particles. In order for a particle to exist, it must possess dynamic content, it must have mass. Before we used $e_0 = m_0c^2$ to provide mass. Now we have used $e_0 = \hbar\omega_0$. Without either we have kinematics and no dynamics, we have motion and no mass, we have points in space-time but no particles.

We got the same results using either $e_0 = m_0c^2$ or $e_0 = \hbar\omega_0$. This was made possible because, as we showed, the photon has rest energy

$$\hbar\omega_0 = m_0c^2. \tag{17}$$

The way to understand eqn. (17) is to say that the photon's rest energy has a mass equivalence of m_0. If the photon's translation were entangled to a short distance, we could put a bucket of photons on a scale and measure its weight because of eqn. (17).

Notice that $\hbar\omega_0 = m_0c^2$ has two extensive variables, ω_0 and m_0. The size of m_0 is determined by the size of ω_0 and changes continuously with ω_0. If ω_0 is zero, the photon has zero rest mass and does not exist. This speaks to the fundamental importance of kinematics. The ratio of $\hbar$ to c^2, $\hbar/c^2$ is a universal constant. Multiply it by ω_0 and you get m_0. But ω_0 is a kinematic variable and m_0 is a dynamic variable. Where does m_0 get its mass units? It gets its mass units from the mass units contained in the universal constant $\hbar$. This is also true for $e = \hbar\omega$ and $\bar{p} = \hbar\bar{k}$. So the creation of type 1 particles, or their materialization, is the process of uniting $\hbar$ with kinematics. The kinematics determines the size of the mass of the particle, while $\hbar$ provides its dynamic content, its mass units. We call this process Materialization or Genesis. It explains how mass comes into existence at the fundamental level. More complicated objects are formed of material objects which have gone through this process.

The photon is the simplest elementary particle we know and as such is ideally suited to illustrate the process by which motion become matter with dynamic properties. But there are other widely known and accepted examples which demonstrate the generality, the universality, of the process at work. One of these is Quantum Mechanics. Perhaps it has never been looked at in this way, but the wave function contains the required kinematics of the system. The dynamical properties of the physical system are obtained by using operators like $E = i\hbar\frac{\partial}{\partial t}$, and $\bar{P} = -i\hbar\bar{\nabla}_r$ which not only perform operations on the wave function to generate the appropriate kinematics, but also multiply the results by $\hbar$ to create the dynamic variables in question. The wave function Ψ is a kinematic function containing the oscillations of the system. Like ω_0, it describes the nature and size of the motion. If Ψ is a constant, there are no oscillations, and no physical system. Only after being operated on by **E** and $\bar{P}$ are the physical properties of the system created and revealed. Notice that $\hbar$ has the units of mvr, so $\hbar\frac{\partial}{\partial t}$ has units of mv^2 or ***E*** and $\hbar\bar{\nabla}_r$ has units of $m\bar{v}$ or $\bar{P}$. The same analysis applies to Quantum Electrodynamics, QED, and will undoubtedly be seen in other theories, for example string theories, devised to describe real particles. These examples argue to the universality of the concept of materialization by which kinematics becomes endowed with mass in the creation of real objects.

Photokinetics, Photogenesis, Photodynamics

In the last section we used the photon and Quantum Mechanics to describe the process of materialization by which real particles are created. Of course the process does not apply to ordinary objects directly, but to objects at a much lower level. In the ordinary world, we are used to dealing with type 2 objects which are usually large collections of other type 2 objects, and as such provide a certain composite appearance. This appearance masks what is really happening within, and must happen for the composite object to exist. We should never forget that things are often not what they seem. We should learn to understand and appreciate the fundamental processes which lie beneath the surface of our reality and make it all possible.

The human body is a good example of well known objects which often conceal unexpected complexities. The human body is a complicated biological structure whose design and function are determined by relatively stable long chain molecules like DNA, RNA, proteins, etc. These and other molecules and the atoms of which they are composed achieve their stability, at every level, through the process of minimization of their internal energies, just like the photon. For example, the proteins twist, bend, and fold in order to minimize internal structural energy, and in the process create a variety of useful, stable structures used by the body. Of course, the interactions, at a lower level, are those of the atoms of which they are composed. And the atoms require the continuous exchange of virtual photons to exist, and to interact with other atoms. And then there are the nuclei, the nucleons within, and the fundamental particles of which they are composed. The point is that things are not what they seem, and we should not be surprised with hidden activity and structures at a more fundamental level, as we have seen with the photon.

Even as seemingly simple, useful, and ubiquitous an elementary particle as an electron is not what it seems. The electron participates in most of today's marvellous technological products, yet we seldom think about it, and certainly not about its necessary interactions with the world which make its existence possible. Its charge, e, defines the unit of charge, yet some well-known elementary particles such as the neutron and proton are composed of quarks with charges 2e/3 and −e/3, and anti-quarks [2,3]. What are the mechanics by which fractional charges are created and how do quarks maintain these charges? It's hard enough to explain e without having to explain exact fractional components of e. We are told that the electron is a point particle with an electric field that extends to infinity. Yet you don't have an electron if you get rid of its electric field. So what's the point? Besides, a point is a very small volume of space-time in which to locate mechanisms that generate spin, mass, and electric charge. You shake an electron and it gives off photons, and when you stop shaking it, it returns to what it was before. It has a bare mass and a bare charge of infinite size, both of which have to be renormalized by interacting with virtual photons and virtual electron-positron pairs to produce its finite mass and charge. Dirac linearized and quantized its energy-momentum to obtain the relativistic properties of the electron, and revealed the necessity of positrons in the process. He showed that the instantaneous speed, not the average speed, of the electron is c [4]. Why? Why not? Like the photon, what other universal speed is available at the fundamental level to provide the kinematics that is needed for all electrons? This phenomenon is called Zitterbewegung [5]. Efforts have been made to describe Zitterbewegung as activity occurring within the body of an electron of finite size [6]. The electromagnetic field, when quantized, displays energies $E = n\hbar\omega$ as well as quantized momenta. The electromagnetic interaction involves Sommerfeld's dimensionless fine structure constant $\alpha = \frac{e^2}{\hbar c}$ [7]. The mysterious fine structure constant, unlike c and $\hbar$, has no units. Its origin, use, and measurement have been extensively discussed in the literature [8]. Notice that α makes e^2 proportional to $\hbar$. It also shows that electromagnetism is constructed using both c and $\hbar$. Clearly even as simple an elementary particle as an electron is an average of a multitude of complicated, unseen processes constantly underway involving the universal constants c and $\hbar$. By comparison, the internal processes we have discovered, using c and $\hbar$ to create a photon, are remarkably simple. We are indeed fortunate to have an unbound fundamental particle, like the photon, to teach us what is going on at the fundamental level.

We have learned an important lesson in studying the photon. After removing the complication of its translation at the speed of light by examining it in its rest frame, we found that it consists of circular rotation at the speed of light with frequency ω_0. We did not find a ball of matter, something small and hard involved in this motion, but rather just motion at the speed of light, what we call Photokinetics. To change the kinematics into dynamics, we multiplied ω_0 by $\hbar$ to get the rest energy $\hbar\omega_0$. This allowed us to generate the energy-momentum theorem of the photon and to produce Photodynamics. We showed that the rest mass of the photon is the mass equivalence of the rest energy as given by $\hbar\omega_0 = m_0c^2$. Only after combining the kinematic content of the photon with $\hbar$, was the rest mass of the photon created. We called this process Materialization or Genesis of material particles. Because the kinematics is motion at the speed of light, the process is best known as Photogenesis.

We must acknowledge that m_0 is a real mass, having mass units, and capable of being weighed. We think it likely that all mass, at the fundamental level, originates from photogenesis, although the particles involved may not possess a flight axis. We notice that the size of the mass, m_0, is determined by the size of ω_0. The higher the frequency, the greater the mass. If $\omega_0 = 0$, the mass does not exist.

Excluding gravity, we have only two universal constants to explain physics at the fundamental level, c and $\hbar$. The constant c is used to create photokinetics; $\hbar$ is used to provide dynamic content; together they are used to create real particles in the act of photogenesis. There is no reason to restrict photogenesis to the photon, and every reason to use c and $\hbar$ in a similar but more entangled and restricted fashion to create other particles at the fundamental level. The fine structure constant, if we look at it properly, says that the electron is composed of c and $\hbar$, and therefore, by extension, also QED. Somehow c and $\hbar$, and G if we include gravity, have to conspire to create reality. It would appear that Photogenesis is the relevant mechanism and has universal applicability. Accordingly, using the photon as a prime example of what happens at the fundamental level, we put forward the following propositions, which we believe to be true:

(1) Photokinetics: At the fundamental level, all particles, even if their translations are restricted, participate in motion at the speed of light.

(2) Photogenesis: At the fundamental level, all particles originate through the process of combining photokinetics with fundamental constants, primarily $\hbar$, which provide them dynamic content. This is how motion becomes matter.

(3) Photodynamics: At the fundamental level, all particles participate in photodynamics.

Concluding Remarks

We constantly marvel at how simple the world appears in spite of the hidden complexities that make it all possible. Yet the hidden parts, in all their complexity and hidden motion have a stability and strength all their own upon which the rest of the world can be built. We described the inner structure of the human body and a seemingly simple elementary particle, the electron, to get this point across. Yet at the fundamental level, the mechanics at work, although well hidden, have to be much simpler, because they have only two universal constants to use as building blocks, c and $\hbar$, excluding gravity. The photon shows us the path to follow, using these constants, to construct reality. The constant c is used to create photokinetics; $\hbar$ is used to provide dynamic content; together they are used to create real particles in the act of photogenesis.

One night I tried to imagine what the photon would look like if I were a point near its centre looking outward. This put me in mind of the words of the poet Henry Vaughan in his poem *The World* [9]:

I saw Eternity the other night,

Like a great ring of pure and endless light,

All calm, as it was bright,

And round beneath it, Time in hours, days, years,

Driven by the spheres,

Like a vast shadow moved; in which the world,

And all her train were hurled...

As gramps said in *On Borrowed Time*, "Eternity is a right smart piece of time." The closest analogy we know of is photon flight for 13.8 billion years. Photodynamics ensures that a photon can spin at the speed of light and fly forever, and, as an aside, the world and all her train would not exist if the photon and its endless rotation at the speed of light did not exist.

I am sure that Henry Vaughan did not know what a photon is, yet having once read his words, one can never forget the vision.

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