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Electron, matter and mass: a new theory

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Abstract

This article shows that empty space, matter and electric charges have a strong link with the vacuum, a link of nature, and that it is thus possible to better understand the substance-space-emptiness proposed historically by Einstein shortly after the publication of his theory of general relativity and again at his Leiden lecture in 1920.

Introduction

In 1905, Einstein thought he could give up on the existence of a particular medium for the propagation of electromagnetic waves, "he didn't need this hypothesis"; but he was careful not to assert that it didn't exist, which enabled him, in 1920, to return to this question by maintaining that the ether¹ really does exist, but that it is endowed with three essential characteristics that rule out any possibility of its direct observation and demonstration:

- It is structureless, a property that has no equivalent in our representation of the world in which we evolve,
- It verifies the mathematical relations expressing the Lorentz transformations that synthesize the two fundamental hypotheses of relativity,
- It has zero mean energy.

At the same time, in the first half of the twentieth century, quantum mechanics argued for the existence of virtual particles that could be extracted from the vacuum in the form of particle-antiparticle pairs which, in the absence of an external energy input, rapidly recombine and disappear into the vacuum in accordance with Heisenberg's incompleteness relations.

The aim of this article is to propose a new interpretation of the nature of empty space, of matter and its principal characteristic, mass, and of the electric charges carried by individual quarks, the elementary building blocks of all matter.

Why these three physical objects? If we accept as correct the Big Bang hypothesis describing the birth of our universe, then empty space appeared first, followed immediately afterwards by the elementary particles, leptons and quarks. These particles all carry electric charges. Matter, empty space and electric charges are therefore the three primary quantities from which everything we observe was formed. Of course, another quantity is created at this moment: time. For reasons that will gradually become apparent, this quantity will be dealt with only briefly here. It will be the subject of a separate article at a later date.

Empty space

Relativity demonstrates that the length of the velocity modulus of any object in relativity retains the same value as the universal constant c , which is also the speed of light in empty space. We do not perceive this displacement, but only those relative to a particular observer located in our three-dimensional space. We can therefore assume that any measured speed is merely the projection of a true speed in our Euclidean space. Since electromagnetic waves propagate at a speed of value c , we can assume that this phenomenon takes place entirely in our usual space. But since all objects move at a slower speed, they must actually be moving in a direction that escapes our perception, making only the projection of this speed in our usual space accessible to us. We are therefore led to attribute at least one additional spatial dimension to real space. This possibility was proposed by Kaluza² and submitted to Einstein, who found the idea interesting. Kaluza and Klein went on to explain why our senses don't perceive this additional spatial dimension by attributing to it the characteristic of being wound around itself along a diameter close to the Planck distance, i.e. around 10^{-35} m.

Admitting that any object can move at speed c in any spatial direction is in opposition to relativity, which postulates that no energy, i.e. mass, can move at this speed. To comply with this fundamental postulate, we have to admit that this rule only applies in our usual three-dimensional space, the subspace of real space.

The substantiality of empty space

Space is mostly empty. In fact, it is customary to teach that the density of matter in the visible universe is very low, almost negligible³, which allows us to model interstellar dust clouds as perfect fluids.

Quantum physics tells us that the mass of any particle is the result of the interaction of the field that describes it with the Higgs scalar field, which is an intrinsic characteristic of the vacuum, giving it a non-zero energy density. It is then necessary to conventionally choose a point of zero energy that satisfies both the founding assumptions of quantum mechanics and avoids the appearance of infinite values in the mathematical equations constructed to serve as an explanatory model. This potential energy of the vacuum can be defined as the so-called zero-point energy, i.e. the minimum energy of all the virtual particles that are present in this vacuum in a potential state and that could be extracted from it. The energy of this vacuum is quantized and non-zero, by assumption. If the average value of the field operator is zero everywhere, the average value of certain functions of this operator is not. What's more, these are manifested in observable phenomena such as the Casimir effect, where two parallel uncharged conductors attract each other in "empty space". This effect is attributed to vacuum polarization. The extraction of pairs of particles and antiparticles endowed with mass can then be explained by considering that these particles are simply volumes of space-time⁴ animated by a certain dynamic⁵.

The theory of relativity, on the other hand, maintains that the average value of vacuum energy is either zero or very small, as suggested by the very low value obtained for the cosmological constant Λ supposed to represent it.

What does the expression "zero mean value" mean here? The zero value of a quantity may in some cases be no more than a convention, a contingent decision. The Standard

Cosmological Model, for example, recognizes that the vacuum is substantial and has a primordial energy, but does not say what this energy will be when all the particles in the universe are extracted from the vacuum. The remaining particles, after the supposed process of recombination with antiparticles, would represent the building blocks of the world as we perceive it. If this hypothesis is a good approximation of what really happened, the vacuum we now observe still contains a quantity of energy corresponding to all the particles that can still be extracted from it.

We also need this vacuum energy to understand gravitational waves and the energy transport they carry out, a transport validated by measurements made when two black holes merge in a coalescence phenomenon.

Of course, we can't define an absolute level of vacuum energy, which would be meaningless. We need to choose a conventional reference frame, one that can simplify mathematical models and enable us to make verifiable predictions. Choosing a reference of zero vacuum energy is contingent, and limits the validity of assumptions made a posteriori to this choice of zero reference.

Defining energy as coming from or identifying with this empty-space "substance" leaves the definition of energy as an object unanswered, and presupposes an energy-laden front about which we can say nothing. This confirms the relativistic idea of endowing the vacuum with a real and substantial character, as well as an energy of non-zero density, even if the latter can be set to zero by a change of origin.

The concept of energy

Is energy a consequence of time, or its cause? Can energy exist without time? These questions can be answered in several contradictory ways. The unfolding of time is observable through a modification of our environment, and in this sense it is associated with energy, since we cannot conceive of modification without the transfer of energy. But time as the cause of energy would mean assuming that it is time that drives the concept of energy - a conclusion we cannot accept.

Substantiating action and identifying it with empty space represents a leap in our intelligibility of the world we perceive. This leap is all the more important as we have the greatest difficulty in constructing a mental image of such a substance, which is at least four-dimensional, without structure, and which could be of infinite value by freeing itself from the conventional reference of a zero-mean value. This raises the question of the relativity of all the laws of nature to such a state of stationary energy. After all, if we build physical theories on the a priori assumption of zero average vacuum energy, then taking into account an energy density of this vacuum-space substance, of this ether, that could be infinite, falsifies all our representations, mathematical models included. Are we at the limit of human understanding? We can only hope that human thought will be able to go beyond this limit in the future.

Matter

The very concept of matter has been, and remains, the subject of profound controversy and questioning. The question raised by one of its characteristics, mass, is announced as being explained by interactions between quantum fields, but in reality this is only really valid for three particles, the three bosons of the weak interaction: the Z^0 , W^+ and W^- bosons, and this

explanation does not constitute a definitive answer to this characteristic of mass. According to this process, symmetry breaking leads to a transfer of energy from vacuum to matter to form mass, a potential energy. Matter and its principal characteristic, mass, therefore have a common origin: the vacuum-space we've just likened to a substance without structure but endowed with energy, Einstein's ether.

Why did all the particles extracted from the vacuum at the big bang include both matter and electrical charges? Are these two quantities linked to the vacuum-space-time, to the ether?

The Standard Model of quantum physics describes the components of observable matter with a limited number of so-called elementary particles, i.e. particles with no identified structure. It represents each elementary particle by a quantum field, and gives these elementary particles a zero dimension. Like all fields, it is defined in all space and gives the probability of finding the particle at a particular point in space-time. It explains and calculates all the observed properties of a particle: charge, spin, but not mass, which must be measured.

The Standard Model not only describes the internal structure of particles and their characteristics, it also describes the four known interactions between these particles, their modeling by quantum fields, enabling us to understand the world in which we evolve.

When two quarks interact by strong interaction, they exchange their "color": a "green" quark that has interacted with a "red" quark becomes "red", while the other becomes "green". This exchange of color is achieved by the exchange of a gluon, the "carrier" particle of the strong interaction. The exchanged gluon therefore carries a color charge, unlike in the case of electromagnetism, where the photon has a zero electric charge. Possessing a color charge, the gluon can therefore interact with another gluon, and it is this property that, according to the standard model, is at the origin of asymptotic freedom. This explanation must be treated with caution, however, as the reality of color charges remains a mere mathematical conjecture. Nevertheless, this complicated representation of the strong interaction has the advantage of responding to the observations made in the various analyses of known phenomena.

For the time being, therefore, this "color" concept is merely an ad hoc explanation, a sort of best compromise to satisfy the standard interpretation, but it does not respond to any observations confirming the existence of charges of a triple nature.

Gluons are described by the Standard Model as having identically zero mass, and therefore travel at the speed of light. The nullity of their masses theoretically allows for strong interactions at infinite distances, but does not allow us to understand the origin of the mass observed for particles like the proton or neutron. This contradiction can be circumvented by explaining that the phenomenon of quark confinement in hadrons limits the effects of the strong interaction inside atomic nuclei, and thus unobservable long-range action. Although insufficiently convincing, this theoretical model is accepted, for want of a better word, by the physics community and is taught to students.

This raises a number of questions about the very concept of matter:

- Is matter a particular state of the vacuum-space-time substance, Einstein's ether?
- Does the characteristic of non-zero mass correspond to a specific dynamic of this ether in the volume of the particle?
- Does this dynamic require an additional spatial dimension?

- Can the nature of matter, with its two main characteristics - electric charge and mass
- be explained in a space with only three spatial dimensions?

We'll try to put forward a partial answer to these questions here, reserving the question concerning the nature of electric charges for a discussion in the next chapter. But to do so, we must first consider several facts. When an electron encounters a positron, its antiparticle, the result is the generation of two photons, ensuring the conservation of both momentum and mass energy (511 keV for each particle). So we observe a complete transformation of a massed quantity of matter into energy.

One possible solution would be for this matter to be a dynamically animated volume of space-time. To accept such an idea, we have to agree with Einstein's concept of a substantial space-time, endowed with a density of action, and to conceive of a particle as a finite volume of this substance animated by a dynamic. This line of reasoning, combined with empirical evidence⁶, reinforces Einstein's idea that empty-space-time substance may be the only primary magnitude in our world. While it confirms the natural link between Einstein's assertion of ether substance, the nature of matter and its transformation into pure energy, then transported by a perturbation of the vacuum substance from close to close, it necessitates the introduction of a new hypothesis: a vortex structure of all elementary particles.

This leads us to the hypothesis that the structure of each elementary particle is described by a turbulent structure of the empty substance within the particle. A particle would then be no more than a kind of local "vortex" of the ether⁷ substance. But if a particle of matter can be described by a vortex of ether, what characteristic of the latter represents its mass?

We know that charged particles move with a speed less than that of light, although the modulus of their velocity remains equal to c . We have concluded that these particles can only move in a space with at least four spatial dimensions. Can we deduce from this that for a particle with no electric charge, such as a photon or neutrino, which can only move at a velocity equal to c , these particles must be fully described in our three-dimensional space? If such particles only move at this speed, this could be understood as proof of their definition in this three-dimensional subspace. Particles with at least one electric charge would then be defined in a space-time with at least four spatial dimensions, a five-dimensional space-time as suggested by Kaluza.

We will therefore introduce the hypothesis that these particles do indeed require at least a fourth spatial dimension, leading to a theory of relativity in at least five-dimensional space. In such a model, we will postulate electric charge sink or source structures, which will ensure the coherence of our model and the cohesion of elementary particles requiring a space with at least four spatial dimensions.

With uniform translation and constant velocity, the emission or absorption of ether, the space-time substance, by these well or source vortices remains symmetrical, and if this substance has a characteristic similar to superfluidity, then there is no friction, and therefore no impediment to motion; but if motion is accelerated, the situation is different: the asymmetry generated can oppose motion, resulting in the appearance of a force that we'll call inertial.

So what do our hypotheses imply? We've explained that matter can be considered in two different ways, the first being in a three-dimensional geometry, Euclidean space, and the

second requiring relativistic space-time, but in a five-dimensional space. Matter then becomes a simple dynamic, within a finite volume, of that ether finally affirmed by Einstein, a localized dynamic in the form of "pseudo-vortexes". This representation of swirling matter is not new, since it had already been proposed by Lord Kelvin, but at the level of atoms considered as minimal, independent entities, as Democritus had already thought. Although this idea met with some success at the time, it was eventually abandoned as it led to contradictions with experimental facts, an atom being very different from an elementary particle such as a quark or an electron.

The concept of mass

According to Einstein's relativity, gravity is the consequence of the curvature of space-time at the point of measurement. Mass is only perceptible to our senses through the effects of gravitation and inertia. Mass, the concentration of energy in a volume of matter, is linked to the curvature of space-time, while inertia could be described as the effect of the "braking" of a massive body accelerated in a vacuum, the latter acting as a "pseudo-friction force" but only manifesting itself for non-zero accelerations, much as a perfect fluid behaves.

The curvature of space-time is not perceptible by our sensory system, and remains difficult to measure by our measuring devices.

In the case of matter, the mass characteristic is the measure of this potential energy. An analogous case is that of an electromagnetic wave; here it's not the photons that store energy, since their mass is zero, nor is it the associated electromagnetic wave, since the ripples are orthogonal to the photons' trajectory. Some physicists believe that to answer the question of energy transport by an electromagnetic wave, we need to examine its interaction with the space-time vacuum, which could temporarily cede this energy to the photons under the effect of the disturbance generated by the associated wave. Physics has yet to provide a definitive answer to this question, although gravitational waves do use this mode of transport for radiated energy.

The theory of relativity postulates that the energy of the vacuum is zero on average, allowing space-time to be flat. This seems to be in line with several experiments, including the measurement of the cosmological background (CMB) by the Planck satellite⁸ since 2004. But if the energy of the vacuum, and therefore of space-time as a whole, is of zero density, where does the energy equivalent to all the mass in the Universe come from? How does this energy, this mass, relate to space-time? This link exists, since the presence of mass at a given point in space-time will result in its curvature, correctly described by the equations of general relativity. This brings us back to a structure of space with at least four spatial dimensions.

While relativistic mechanics defines masses as fixed quantities of energy, some⁹, as we've said, don't hesitate to conceive of them as volumes of space-time folded in on themselves¹⁰¹¹ and animated by vibratory or rotatory movements.

There is a contradiction between the definition of energy as a potential for action, and its substantial characteristic given by the relationship between mass and energy: Higgs hypothesized that mass is merely the result of the interaction of a quantity of energy localized in a particle with a scalar field known as the Higgs field¹². In other words, a particle's energy, its mass, is a direct consequence of its interaction with the vacuum, with the scalar vacuum field providing the link. In this model, mass energy is an action potential frozen in a limited

volume. If energy is transferred to a particle by obtaining mass, this energy must somehow be taken from the vacuum. One solution might be to describe the interaction of the vacuum with the matter of a particle as a "setting in motion", a dynamic of the vacuum-space substance in a small volume.

Electric charges

Let's look at the interaction between two static charges, two electrons. The presence of each electron gives rise to spherically symmetrical electric fields centered on each of the two electrons. The result is a force proportional to the product of these charges and inversely proportional to the distance separating them. Energy is therefore transferred to each of the particles as they move under the action of a force. Where does this energy come from? From charge, but then how was it stored?

How did elementary particles like electrons and quarks come to be endowed with an electrical charge? What was the process involved in making these charged particles? What is their necessity in the Big Bang phenomenon? If space-time was the first structure to be generated, then all matter particles were extracted from the space-time void and must therefore have a causal link of some kind with the void-space substance. But even if this link is proven, it doesn't justify the necessary existence of electric charges unless they, too, present a strong link with empty-space substance. We are thus confronted with the hypothesis that matter and electric charges could have the same causal and natural link: ether substance, the structureless space-time void.

The interaction between these two charges will generate a force on each of them, and thus an input of energy. This transfer of energy allows us to conclude that the electric field will contribute a quantity of potential energy, which cannot be taken from the total energy of the other charge if it remains stationary. But we know this can't be the case, because if a static electric field carried energy, where could it come from? So where does this energy come from, transmitted to the charge that will set it in motion under the action of this electrostatic force? It can only come from a temporary borrowing from the empty substance, from its zero-point energy, as the electric field creates the necessary conditions for a local withdrawal of the quantity required for the space-time vacuum postulated by Einstein as the basis for the theory of general relativity.

We analyze the presence of this electric field as an indication of ether exchange between two types of space, the particle's four-dimensional space and our own three-dimensional space plus time. We must then represent these charges as a kind of energy source or sink, distinguished by the sign of the charge carried by the elementary particle. According to this model, the electric field is understood as a "pseudo-pressure", which is nevertheless different from that measured in a fluid, since the ether we're talking about is postulated to be structureless, unlike any fluid, which must be made up of particles, atoms or molecules. The magnetic field thus becomes the image of the dynamics of Einstein's empty-space substance. It can only be observed in reference frames that are in motion relative to electric charges. As for the charge, since the vortex can suck in or project quantities of this ether, the electric charge will be described in terms of sink or source flows.

In the equations of relativity, electric charges are physical invariants, remaining identical to themselves whatever the velocity measured in an inertial frame of reference, which supports our electric charge model.

Matter constrained to a strictly limited volume forces the ether substance to circulate in such a way as to describe curves leading to the appearance of an acceleration, this ether representing a certain density of energy. It is this acceleration that will be the mark of a particle's mass. A static gradient will present straight lines of circulation, and therefore an absence of transported energy. In the case of an electromagnetic wave, the energy at any point is not "carried" by the wave, but generated by the non-linear fluctuations to which the empty substance is subjected. Instead of being transported, vacuum energy is used at every point.

Bringing quantum and relativistic mechanics closer together

By changing the rules to which we've been accustomed since birth, relativity profoundly transforms the image of reality we have of our everyday space and its properties. Where scalar products describe orthogonal straight lines, i.e. at an angle of 90°, those of relativity's of Minkowski or Riemann spaces, with a Lorentzian metric, will define orthogonality as symmetry with respect to a light vector. The distances between two event points will have the value:

$$ds^2 = dx^2 + dy^2 + dz^2 - c^2 dt^2$$

This addition of the term $-c^2 dt^2$ is no mere sleight of hand. It reflects the need for a fourth spatial dimension to describe each dynamic phenomenon in terms of its position in this four-dimensional space.

This leads to the definition of a conserved quantity which, for light, can be written as:

$$ds^2 = 0$$

Let's consider the definition of the velocity vector of an object in this representation of space-time. This velocity vector is a 4-vector whose norm is always equal to c :

$$\vec{v} = \left(c \frac{dt}{d\tau}, \frac{dx}{d\tau}, \frac{dy}{d\tau}, \frac{dz}{d\tau} \right)$$

$$\sqrt{(\vec{v}, \vec{v})} = \sqrt{c^2 \left(\frac{dt}{d\tau} \right)^2 - \left(\frac{dx}{d\tau} \right)^2 - \left(\frac{dy}{d\tau} \right)^2 - \left(\frac{dz}{d\tau} \right)^2} = c$$

Moving at the speed of light means, according to the choice of this metric, concentrating all the points making up this line at a single point, that of the observer moving at this speed, and thus allowing past and future events to meet at this point.

How can we interpret this constancy of the velocity modulus? Let's consider a photon moving along a geodesic line, i.e. without interacting with a massive object. We can observe this photon as it moves at a velocity c , which is fully described in our three-dimensional space, whereas for any object that is stationary relative to any reference frame, we could only understand the length of its velocity vector of value c by assuming that this object moves at

this velocity along a dimension orthogonal to the three spatial dimensions of Euclidean space, so that we can't observe any displacement other than that in the direction of time. What could this dimension be? The temporal dimension? An additional spatial dimension, as suggested by Kaluza and Klein¹³? In this respect, the quantity of motion is highly instructive. In the usual three-dimensional space, this quantity is expressed by the relation:

$$\vec{p} = m\vec{v}$$

In relativity space-time, momentum will be described by the 4-vector impulse \vec{P} :

$$\vec{P} = mc\vec{u}$$

Where \vec{u} is the velocity 4-vector of an object. This velocity vector will have coordinates:

$$\vec{u} = \left(c \frac{dt}{d\tau}, \frac{dx}{d\tau}, \frac{dy}{d\tau}, \frac{dz}{d\tau} \right)$$

This leads to the 4-vector impulse:

$$\vec{P} = (\gamma mc, \gamma m\vec{v})$$

What's interesting about this mathematical representation is that, since impulse is a conserved quantity independent of the observation frame of reference, the same applies to its coordinates and therefore to the quantity γmc along the temporal direction of space-time. Thus, the formalism associated with relativity leads us to interpret this constant-modulus velocity as a displacement of all objects, whether massive or not, at a speed c along a privileged direction, that of a fourth spatial dimension, since the time dimension cannot logically be retained as the direction of all matter, since time is used to describe motion and transformations. This conclusion is counter-intuitive, but so was the metric introduced by Einstein, and yet we have shown it to be the only logical possibility if we accept the principle of causality as fundamental.

Relativity describes quantities such as position, distance and velocity in terms of 4-vectors. The position of an object, for example, is described by four coordinates:

$$x^\mu = (ct, x, y, z)$$

This leads to the definition of a pseudo distance ds :

$$ds^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2 = c^2 d\tau^2$$

We have shown that this definition of distances is the only logical, if highly counter-intuitive, solution. When the object moves at speed c , its mass being zero, we obtain a zero length for the interval ds :

$$ds^2 = 0$$

This corresponds to the ellipsoid of light cones. For any particle of non-zero mass m , an interval ds cannot be zero. In this equation, time τ is the particle's own time, measured in a comoving frame of reference, i.e. linked to the moving object. The term $c\tau$ is therefore directly and uniquely linked to the particle's internal structure. Let's now consider a five-dimensional spacetime by adding a new spatial coordinate x^4 of value $c\tau$. The pseudo-distance interval dS can be written as:

$$dS^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2 - c^2 d\tau^2$$

Having chosen this fifth coordinate, the value of the new interval will be zero:

$$dS^2 = 0$$

This means that in this five-dimensional space-time, any object, massive or not, moves in this additional dimension at a speed equal to c . Such a space is similar to that proposed by Kaluza and modified by Klein. By performing this operation of adding a spatial dimension and modifying the writing of the pseudo distance dS , we reinterpret the space of our reality. Although this additional dimension is necessary, according to our hypotheses, to explain the nature of mass, we come up against the question of the imperceptibility of this dimension by our sensory system. Kaluza and Klein hypothesized that this dimension was wrapped around itself with a very small diameter¹⁴, totally beyond the reach of any detection. This is because, in our model, this additional dimension is only accessible inside particles or elementary charges, and would therefore only apply to a comoving reference frame linked to the particle, i.e. to its internal dimensions. It would only reveal itself when the space-time substance is animated by a rotational dynamic.

The advantage of generalizing the relativistic model to such a space is that it provides a natural explanation for the appearance of Maxwell's relations, which are not structurally modified in the relativistic model because, as Feynman¹⁵ rightly points out, Maxwell's equations already take into account the v^2/c^2 terms specific to relativity theory.

The quantity dS doesn't define the proper time of five-dimensional spacetime, but the evolution of the particle's internal space, which is described in a five-dimensional space. The added dimension $c\tau$ measures the dynamics inside the particle; proper time is a measure of distance just as time t is Einstein's coordinate time. Based on this idea, C. Bordé¹⁶ concludes that we then obtain a new invariant in relativistic spacetime, which is the action differential:

$$dS = -p_\mu dx^\mu$$

This relationship allows him to write the relationship between the mass m^* representing the overall mass of the object:

$$m^* = m \frac{dt}{d\tau} = \frac{mc}{\sqrt{g_{\mu\nu} \dot{x}^\mu \dot{x}^\nu}}$$

Here, the derivative corresponds to that performed in the frame of reference of the external observer located in relativistic space-time. Note that we can then write these derivatives:

$$\begin{aligned}\dot{x}^0 &= c \\ p^0 &= m^* c\end{aligned}$$

Finally, he obtained the relation characterizing the quantity mass in relativistic four-dimensional space:

$$dS = -dx^\mu p_\mu = -mc^2 d\tau$$

Here we see the difference between the concepts of matter and mass: matter is a limited volume of the substance vacuum-space-time, while mass is a vortex dynamic directed towards an additional spatial dimension, leading to a description of our Reality in a space with at least five dimensions, similar to that proposed by Kaluza and compatible with those studied by string theories.

From the expression of the distance interval dS in this five-dimensional space, we can deduce that the proper time $d\tau$ in a comoving frame of reference, therefore linked to the matter particle, will have the expression:

$$c d\tau = \sqrt{G_{00}} dx^0$$

With G_{00} and dx^0 defined by the relationships in a contramobile reference frame:

$$G^{\mu\nu} = g^{\mu\nu}$$

$$G^{\mu 4} = G^{4\nu} = 0$$

$$G^{44} = G_{44} = -1$$

The distance interval dS can then be written in the contramobile laboratory reference frame:

$$dS^2 = G_{\hat{\mu}\hat{\nu}} d\hat{x}^{\hat{\mu}} d\hat{x}^{\hat{\nu}} = c^2 dt^2 - d\vec{x}^2 - c^2 d\tau^2$$

In the four-dimensional reference frame, the interval dS takes the value:

$$dS = -p_\mu dx^\mu = -mc^2 d\tau$$

This interval is zero for massless particles such as photons, or in the reference frame linked to the internal structure of massive particles.

So what happens to mass in this five-dimensional space? It can be expressed by the relation:

$$\hat{p}_{\hat{\mu}} = m^* \dot{\hat{x}}_{\hat{\mu}}$$

Where:

$$m^* = m \frac{dt}{d\tau} = \frac{mc}{\sqrt{g_{\mu\nu} \dot{x}^\mu \dot{x}^\nu}}$$

As this space is similar to that proposed by Kaluza and Klein, Maxwell's equations appear naturally as a consequence of the chosen metric. From these relationships, we can deduce that the fundamental quantity is the electromagnetic potential A . It is from this quantity that the Aharanov-Bohm effect, for example, can be deduced.

A consequence of this way of interpreting the primary quantities of space, time, matter and electric charge is a mass representing the dynamics of the ether of empty space, i.e. the particle's own internal time.

This mass is measured to be almost zero for neutrinos, which can then be fully described in a three-dimensional subspace, that of our everyday lives, the residual mass being merely an effect of a whirling internal structure. Today, the low values of these masses are not measured; they are only constrained by a maximum value that is continually being revised downwards by increasingly sophisticated measuring devices.

Conclusion

Since the hypothesis of a substantial space-time is the only additional hypothesis, there is no need to modify the relativistic and quantum models, except to extend the spatial dimensions to a minimum number of four, as Kaluza suggested as early as 1920 in his article and in his discussions with Einstein, but without the assumption that this additional spatial dimension is wound around itself. Additions to this model will be necessary to clarify the internal structure of a particle and to specify its mass value. Possible representations have already been suggested in two previous studies¹⁷.

References

¹ Einstein A Leyde conference, 1920

² T. Kaluza, On the problem of unity in physics, Sitzungsber. Preuss. Akad. Wiss. Berlin. (Math. Phys.) 966-972, 1921

³ The average density of matter measured in the universe is between 2 et 4 10^{-31} g/cm³

⁴ Bordé C., (2008), 5D optics for atomic clocks and gravito-inertial sensors, European Physical Journal Special Topics, 163, 315-332 et Bordé C. J., 2014, arXiv:1304.7201 et International School of Physics "Enrico Fermi" - Course on Atom Interferometry (2013)

⁵ This idea is supported by some scientists who believe that matter is a local dynamic of space-time that is consistent with a fourth spatial dimension that escapes our perception because it is perceptible only at the microscopic level.

⁶ Par exemple l'effet Casimir où la probabilité non nulle de l'extraction temporaire de couples de particules et d'antiparticules virtuelles

⁷ For exemple see : C. Bordé 2008, 5D optics for atomic clocks and gravito-inertial sensors, European Physical Journal Special Topics, 163, 315-332 et Bordé C. J., 2014, arXiv:1304.7201 et International School of Physics "Enrico Fermi" - Course on Atom Interferometry (2013)

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