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Photon's Mass (m) is a Function (f) of its Energy(E): m = f (E) (A Possible New Postulate)

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Abstract: Analyzing the numerous effects induced by electromagnetic radiations (EMRs), such as the photo-electric effect, or the Compton effect, in which the photon(P) behaves physically like a microscopic billiard pellet, with mechanical effects superimposable on those performed by massive particles, we suspect that the *momentum*(***p***) of P transports, with its motion, also a *dynamic-mass*, likely in the form of *mass-energy density* (however undetectable during motion: the Complementarity Principle prohibits it). Besides, as Pacini reminds us, '*motion itself is mass*'. Applying the *de Broglie formula* (***p***=*h*/*λ*) to the EMRs, it emerges that the *momentum* (***p***) of an optical P corresponds to $1.325 \cdot 10^{-22}$ [g·cm/s], i.e. values over 100,000 times greater than the *rest mass* of the electron. Planck itself expressed in *erg*·sec, that is, in grams ·cm^2/s, the value of the well-known 'natural constant', *h*, which represents the physical, concrete, real *heart*, of the '*quantum of EMR*', or Planck's grain: how to say P. Thus, the parameter *h* is indicated in grams, values therefore likely referable to a *mass density*, quantitatively *invariant*, even during motion, unlike energy, which instead varies with the wavelength (λ) of the P considered. This is what is correctly found in the work, comparing the values of the Ps *momenta* of different λ, thus confirming that the probable *mass density* conveyed by Ps is a *function* of their energies.

Keywords: Photon (P), Electromagnetic radiation (EMR), Mass-Energy Equivalence Principle (MEEP), Gluon (G), *momentum* (*p*), *gauge symmetry theories* (GST).

INTRODUCTION

As is known, in order to solve the anomalous behavior of the *black body* radiation in presence of high frequencies, Planck was forced to admit that the energy of the oscillators (i.e., the electromagnetic source: an electron, for instance) can coincide only with discrete values, that is discrete quantities defined as *energy quanta*, or "Electromagnetic Radiation(EMR) *quanta*"[1].

Planck revealed, indeed, that he had been able to infer his formula only by admitting that the EM source emits or absorbs energy only in the form of packets of energy(*E*) proportional to their oscillation frequency(*v*) [2].

At this regard, Planck said: "Considering that — and this is the crucial point of the whole calculus — the energy(ε), oscillator energy, is made of a defined number of finished and same parts, we can use to this purpose the natural constant $h=6.55 \cdot 10^{-27}$ [erg·sec]. If this constant is multiplied for the normal oscillators' oscillating frequency, (*v*), we get the *Energieelement*, ε, expressed in erg·sec"[1]:

$$E = h\,v \tag{1}$$

where the quantum h expresses an energy value, as well as a mass-equivalent value, since Planck quantizes this value in erg·sec. In turn v gives the frequency, i.e. the number of oscillations made by Planck's grain(h) in a second.

Thus, Planck "was forced to divide the *Energy* (ε) into blocks of units(packets) *h·v*"[3]. As Penrose reminds us, Eq.(1) indicates the "Planck's Radiation Law"[4].

MATERIAL and METHODS

Following the innovations introduced by Planck, a few years later Einstein wrote that light is not a continuous wave, but is composed of particles, the *light quanta* [5], later called *photons* [6], whose *energy*(*E*) is proportional to *frequency*(*v*), according to *Planck's formula*: *E=h v*.

Feynman points out: "A photon (P) is like a particle, in that it carries an energy and a *momentum*. The energy of a P is a certain constant, called Planck's constant, times the frequency of the P: *E=hv*. Such a P also carries a *momentum*, and the *momentum*(***p***) of a P is *h* divided by the wavelength(λ)"[7]:

$$\boldsymbol{p}=\frac{h}{\lambda} \tag{2}$$

It is common knowledge that the Eq.(2) represents the *de Broglie formula* [8].

As is known, the *momentum* parameter (*p*) was introduced into physics for the first time by Newton in order to calculate how much a body in motion weighs. In the first pages of his masterpiece, Newton reported the following definition: "Quantitas motus est mensura ejusdem orta ex Velocitate et quantitate Materiæ conjunctim" [9], that is, the quantity of motion (*momentum)* is a measure in itself, since it depends jointly from the speed and the quantity of matter of the particle considered. So, Newton defined this *vector magnitude*, or *momentum* ($\vec{p}$), in the following way:

$$\vec{p} = m \cdot \vec{v} \tag{3}$$

where $\vec{p}$ describes the quantity of motion of a body having a mass *m* and moving at a speed(**v**). Hence, the *momentum*(***p***) of a particle is the product of two quantities: the particle's mass and its velocity. Namely, *momentum* is a vector quantity: it has both magnitude and direction, and direction and line coincide with those of the velocity(**v**). In fact, the vector ***p*** has the same direction and the same line of **v** and its module is the mass times the speed module.

Photon's *Momentum*

As it is known, inspired by Einstein's intuitions, according to which light can be associated with particles having a *momentum*(***p***) equal to: ***p*** = E/c = *h*/λ [5], likewise, for de Broglie the inverse process is also possible, that is, associating waves with particles. So, de Broglie proposes that each particle, with mass *m* and velocity **v**, is *associated* with a wave, whose wavelength(λ) is equal to [8]:

$$\lambda = \frac{h}{\boldsymbol{p}} = \frac{h}{m\cdot\mathbf{v}} \tag{4}$$

Thereby, without experimental data, de Broglie suggested to give particles (including photons) the same property as waves. He gave each particle an its own λ, depending only on the ***p*** of the particle itself [10].

In this regard, Polkinghorne writes: "de Broglie had formulated a bold hypothesis: if light, while oscillating, exhibits corpuscular properties, then perhaps it is reasonable to expect, in an equivalent manner, that particles such as electrons exhibit wave properties. de Broglie managed to translate this idea into quantitative form by generalising *Planck's formula*, which had made energy, a typical property of particles, proportional to a wave property: frequency.

de Broglie suggested that another corpuscular property, *momentum*(***p***), was related in a similar way to another wave property, wavelength(*λ*), and that the relative constant of proportionality was also in this case the *Planck's constant*(*h*).

These equivalences constitute a small dictionary for translating from waves to particles and vice versa''[11].

About photon *momentum*, Feynman adds: “That light carries energy we already know. We also know that the energy (*E*) of a light-particle is *h* (the Planck constant) times the frequency(*v*): *E=h v*. We now understand that light also carries a *momentum* equal to the energy divided by *c*, so it is also true that these effective particles, these *photons*, carry a *momentum*(***p***) :

$$\boldsymbol{p} = \frac{E}{c} = \frac{h\,v}{c} \tag{5}$$

where *c* is the light speed in the *vacuum*. The direction of the *momentum* is, of course, the direction of propagation of light”[7].

Staying on topic, let’s read from Fermi: “The photon too, as other particles, is a corpuscle, a *light quantum*, and has an its own *momentum*(***p***), through which transfers all its energy to the hit particle”[12].

Furthermore, it is of fundamental importance to keep in mind that, among the different electromagnetic waves(EMWs) that make up the EM Spectrum, each is characterized by its own *momentum*, the value of which is always different from the values of *momenta* relating to the other EMWs, traveling at different frequencies(*v*) and wavelengths(λ).

On the contrary, if the speed of light, and thus the speed of propagation of the various EMWs, had been only one, i.e. the same speed for all EMWs, equally the value of p should be the same for all the various EMWs. Therefore, let's calculate the relative values of these momenta.

Measurement of Optic Photon’s Momentum

In this regard we make use of de Broglie's formula, illustrated by Eq.(2).Then, we begin to analyze the *momentum* of common visible light, whose average value, as Weinberg reminds us, shows a wavelength corresponding to $5.5{\cdot}10^{-5}$[cm] [13], so we have:

$$\boldsymbol{p} = \frac{h}{\lambda} = \frac{6.626 \cdot 10^{-27}[erg \cdot \mathrm{s}]}{5 \cdot 10^{-5}[cm]} \tag{6}$$

As the *erg* value is expressed in [g·cm/s^2· cm], that is in [g·cm^2/s^2], we have:

$$\boldsymbol{P} = \frac{6.626 \cdot 10^{-27}[g \cdot \frac{cm^2}{s}]}{5 \cdot 10^{-5}[cm]} \quad (7)$$

that is:

$$\boldsymbol{p} = 1.325 \cdot 10^{-22}\,[g \cdot \frac{cm}{s}] \quad (8)$$

As shown by Eq.(8), it is clear that the *momentum(**p**)* of a visible photon(P), expressed in grams, should carry out a *hidden dynamic-mass* [14]. No surprise! At this regard, indeed, Penrose sanctions: '**The mass of photon** is an impalpable type: it **is pure energy**''[4] and Feynman says: "The *momentum*, as a mechanical quantity, is difficult to *hide*. Nevertheless, momentum *can* be hidden –in the electromagnetic field, for example. This case is another effect of relativity"[7].

Complementarity Principle

And why would the possible mass of the P be *hidden*? A well-known principle of Quantum Mechanics(QM), the Bohr Complementarity Principle, could suggest this to us, according to which a moving particle, a motion expressed by the value of its *momentum* and the acquired *kinetic energy* (E_{Kin}), can only manifest its wave behavior, and not the corpuscular one, which instead will only emerge when the particle, or the P, stops its travel, that is, when they interact with matter [15]. This Principle states that each particle can show both its corpuscular and wave-like behavior, but only one at a time: never simultaneously! It is a real *conditio sine qua non*.

Consequently, until the electron or the photon are in motion, and so any other *quantum object*(QO), they can show only their *wave side*. On the contrary, only in the very short time the particles interact, we may indirectly detect some aspects of their *corpuscular behavior* through their quantum mechanical effects [16].

Farmelo summarizes: "As de Broglie was the first to see, radiation and matter are both two-faced: they show their corpuscular side in interactions, and their wave side in propagation. For example, the electron behaves like a particle when experimenters observe its interactions, while it behaves like a wave when they study its propagation. The conclusion of all this is that both light and matter can behave as both particles and waves. Quantum Field Theory has made possible a unified description of radiation and matter'[17].

In short, in order to respect the Complementarity Principle, a particle can show itself only with one of its two 'complementary aspects': wave or particle, but never at the same time. These parameters, indeed, are 'complementary', similarly to the complementary parameters of the Uncertainty Principle: energy-time, or position and momentum of a QO [18]. As it is known, the more accuracy we have in knowing a parameter, the more uncertain the measure of the complementary corresponding parameter will be [19].

On the Massless Photon

This is why, being always in motion, P appears massless to everyone's eyes, since its mass value, strictly connected to momentum, in our opinion, will not be detectable, but remains

hidden [20]. Instead, only when P interacts with matter will it be able to show, for those few moments, its corpuscular behavior and its mechanical effects, as occurs for example with the Compton Effect [21] or the photo-electric effect [22], or it turn (if the energy conveyed is sufficient, i.e. ≥ 1.022 MeV) into a pair of material particles, even of a certain consistency: materialization of Radiation [23].

Well, this could be considered as another point in favor of the non-massless P, given its easy conversion into electron-positron pairs, for example, and vice versa.

In this regard, however, what we read from Feynman is very interesting and decisive: "Finally, associated with the relativity theory, there is a modification of the laws of *kinetic energy*(E_{Kin}), or whatever you wish to call it, so that E_{Kin} is combined with another thing called *mass energy*. An object has energy from its sheer *existence*"[7]. This is a very important, fundamental concept and statement, in which Feynman clearly says that any particle, including photon(P), also possesses and transports with it, together with E_{Kin}, an energy of mass, precisely called: *mass energy*.

Likewise, it may be justifiable to infer that a P also possesses a dynamic mass, although infinitesimal and not directly detectable when in motion: to be exact a proportional equivalent mass energy [24].

Furthermore, Feynman adds: "From now on we can say that the total energy of an object is mc^2.

Therefore, we have a *new idea*: we do not have to know what things are made of inside; we cannot and need not identify, inside a particle, which of the energy is *rest energy* of the parts into which it is going to disintegrate. It is not convenient and often not possible to separate the *total* mc^2 *energy* of an object into *rest energy* of the inside pieces, E_{Kin} of the pieces, and *potential energy* of the pieces; instead, we simply speak of the *total energy* of the particle. We 'shift the origin' of energy by adding a constant m_oc^2 to everything, and say that the **total energy of a particle is the mass in motion times c^2**, and **when the object is standing still, the energy is the mass at rest times c^2"**[7].

Obviously, this also applies to the particle of light, i.e. the *light's quantum*, or P. In fact, Feynman points out: "The quantum behavior of **atomic objects** (electrons, protons, neutros, photons, and so on) is the same for all, they **are all 'particle waves'**, or whatever you want to call them. So what we learn about the properties of electrons (which we shall use for our examples) will apply also to all '*particles*', **including photons of light"**[25].

Mass-Energy Equivalence

Thus, we have acquired from Feynman a fact of very considerable importance and value, as well as rich in meanings and developments in favor of the much snubbed *rest mass* of the P (m_o), considered completely null and void, i.e. equal to zero, as also reported in all school and university texts. Instead, it would seem that, in agreement with Einstein and Feynman, it can have a non-zero value, but corresponding to its *equivalent energy* (E) divided by c^2:

$$m_o = \frac{E}{c^2} \tag{9}$$

which is known above all in the form:$E=mc^2$.

Furthermore, the *soul* of electromagnetic radiation (EMR), as if to say the *soul* of each P, of each *Planck's grain*, is represented precisely by Planck constant(*h*) [26], see Eq.(1), whose value, according to Planck [1], is expressed in *erg* ·sec, i.e. in grams·cm^2/sec:

$$h = 6.626 \cdot 10^{-27}\ [g\ \cdot \frac{cm^2}{s}] \qquad (10)$$

Well, it is superfluous to remind the scientific community that in grams you measure a weight, a mass!

In this regard, as Klein reminds us, Einstein makes a truly unexpected discovery, even if directly linked to his Theory of Relativity. He sends a letter to his friend Conrad Habicht, explaining that his June article ([5]) has another implication [27]. In fact, Einstein writes: "It has come to my mind a consequence of the study of Electrodynamics. The Principle of Relativity, in association with Maxwell fundamental equations, requires that the mass is a direct measure of the energy contained in a body; the **light carries a mass**. A notable reduction in mass should occur in the case of radium"[28]. And so it is! Radium, in fact, as a frankly radioactive element, also continuously emits highly energetic EMRs, so it must also lose mass!

Therefore, in agreement with Einstein, we obtain that: energy loss = mass loss. As we know, in fact, 1 kg of radium loses approximately 1 gram of mass per day. Again in the letter to Habicht, Einstein defines his latest article,[5],"very revolutionary"[28] since, among other things, it contains this surprising concept of **mass as a measure of energy**.

This new concept was reiterated and reinforced by Einstein a few weeks later, in his article of September 1905 [29]. As Klein reminds us, "The calculations reported in this article show only one thing: **a body that emits EMRs necessarily loses mass**. Einstein attributes a universal value to this result, arguing that the mass of a body represents a measure of its energy content. Consequently, if this body loses energy, in any form, it also loses mass"[27].

To this purpose, Klein points out: "From a conceptual point of view, even in this case it is a revolutionary result. Mass, which until then only measured the amount of matter contained within a body, now measures its energy content. **Everybody endowed with mass is equally endowed with a *mass energy***.

As Einstein specifies, the *equivalence between mass and energy* unfolds thanks to the 'mean term' of the speed of light (squared) which unifies two hitherto completely separate concepts. **Even at rest, a body with mass contains energy**"[27] and *vice versa*, as is obvious to deduce.

"Thus, physicists began to understand that, in the energy balance of any physical process, it must be taken into account that **everybody, even at rest, contains a certain 'mass energy'**. Thus, in a nuclear reaction mass is generally not conserved, and mass loss results in energy release"[27].

And in fact it is commonly recognized, as also repurposed by Artificial Intelligence, that mass is a form of energy and the two are equivalent and convertible into each other. This means that **everybody with mass has an intrinsic "rest" energy**, which can be enormous even for small masses if multiplied by c^2. In fact, "every body endowed with mass is equally endowed with a *mass energy*"[27].

Klein wonders: “But if the link between mass and energy is so intrinsic to matter, why can't we perceive it in everyday life? Simply because it is too small in size compared to the orders of magnitude we are familiar with. Even the smallest grain of dust is a prodigious store of energy, even if we cannot perceive the energy contained in its mass”[27].

Galison writes:“ Einstein was unsatisfied: he was not satisfied of the analyses of the light. Einstein stated that *to any kind of energy is associated a mass*”[30].

Thus, according to Einstein, there should be also a mass associated to the photon(P). Galison continues: “Planck stated that also the transfer of heat adds a mass”[30]. Well, what is heat made of? As is know it is made of EMR, that is Ps. Thus, according to Planck, a transfer of radiation, of Ps, from A to B will cause an increase in the mass of B.

“It seemed that a hot pot was heavier than a cold one, although exactly the same size. It was a new idea: in Newtonian physics there was nothing suggesting a variation in mass as a consequence of the energy”[30].

Thus wherever there is a body, or particle, having energy, there should be in a way (visible or hidden) a certain mass too, and *vice versa*: this is what comes from Eq.(10) [31].

Einstein adds that, based on the calculations of its article [29], it emerges that a body that emits EMR necessarily loses mass! According to Hawking, this should also happen with the *evaporation* of Black Holes(BHs)[32].

In this regard, indeed, it seems scientifically very interesting to bring to mind that, as deduced by Einstein, was fully collected by Hawking, applying it precisely to the Black Holes (BHs)[33].

In fact, one cannot overlook the famous hypothesis of the *evaporation* of BHs proposed by Hawking. He writes: "It seems that any black hole will create and emit particles such as neutrinos or photons....As **a black hole emits this thermal radiation one would expect it to lose mass**”[32].

Well, it is not possible to be clearer and simpler than this: the loss over time of “thermal radiation”, i.e. photons (Ps), causes the BH to lose mass in parallel!

It is a prestigious confirmation of the Einstein’s *mass-energy equivalence principle*(MEEP), authoritatively, and without any hesitation, applied by Hawking also to the P, and of the no further sustainability, in our opinion, of the concept that the P must be completely massless! With such a prediction, Hawking provides a precious and highly qualified confirmation of the profound concept of MEEP, with all the implicit consequences and potential implications and applications, in addition to the various related mechanical phenomena [34].

In this respect, analysing a lot of ordinary physical phenomena, it seems that sometimes the P, rather than a particle made merely by energy, behaves like a particle incorporating a certain mass, though infinitesimal, but not always insignificant or effect less. Several physic phenomena, in which the P is involved, are not completely explainable only with the energy of the P, but they make us think that the P under its energetic *shape* could also *hide* a mass.

Mass which we cannot see when the P shows its *wave-like aspect* [35]. In fact, in agreement with Bohr Complementarity Principle [15], only when P stops travelling it can

show its *corpuscular appearance*, and in that occasion we can hope to detect the probable mass of the P (maybe not directly, that is observing its effects).

In this regard, a clear mechanical effect induced by P is described by Hawking himself: “If a real P collides with an atom, it will move an electron from an orbit closer to the nucleus to one further away. This movement uses the energy of the P”[36]. Why cannot we suppose that at the bottom of this phenomenon there is a strictly mechanic action of the P, which with its energy-mass would raise the *kinetic energy* of the orbiting electron from which it was absorbed?

This goes along with the fact that just after an attosecond (10-18 sec) the electron get free from the mass-energy of the P and goes back to its previous orbit, the one with a minor waste of energy [35].

In other words, the excitation and un-excitation of the electron, and thus of the atom, should not depend on a merely energetic effect, but also on a specifically mechanical effect, as a consequence of the probable mass (mass energy) of the P. This shows the assumed “mechanic effect” determined even by a single P, and able to hit an electron and move it away. Yet the P is mass less! How can a particle, without the least mass, make an electron splash off a metal? It seems more likely that it is a body having mass to move an electron on a more external orbit energy [35].

Furthermore, that the P also transports and transmits a mass value, Feynman tells us indirectly, from which we read: “If electrons were ideal, and went from one point in space-time to another following only direct paths, there would be no problem: n would be only the mass of the electron (determinable during observation) and j would be its charge, that is, the probability amplitude of interaction between the electron and one or more Ps (which can also be determined experimentally). But ideal electrons do not exist and real ones, from time to time, emit or absorb their own Ps. Therefore, the mass of the electron (measured in laboratory) depends on j, i.e. the amplitude of interaction with Ps”[37].

It’s like saying that the mass of an electron depends on the number of Ps in charge, that is, on the quantity of Ps emitted or absorbed. In other words, Feynman, one of the most expert in the secret of light, is telling us that a single extra P, absorbed by the electron, is able to increase the value of the electron's mass, while an emitted P, that is, one less P (in charge of the electron) decreases its mass! [38].

Only what Feynman has now described, in relation to electron-photons interactions, which are the essential foundations of Quantum Electro-Dynamics(QED) and “concern most of the most common phenomena, for example all chemical and all biological phenomena”[37], would be enough to allow us to propose the concept that P is not entirely massless, although not in line with the common orientation of the scientific community. Therefore, let us delve deeper into this topic, specifically concerning the rest mass, or inertial mass(m_o) of P.

RESULTS

Photon’s Rest Mass (m_o)

It seems really of considerable importance to keep in mind how Einstein himself commented upon his *mass-energy equivalence principle*(MEEP):“The value of the considered mass refers

to the value of an *inertial mass"*[30], that is, identifiable with the *rest mass*(m_o). In fact, Einstein connsidered the MEEP as "the connection between *inertial mass* and energy"[30].

In this regard, during his Lectures held at Princeton in May 1921, Einstein describes other implications resulting from his MEEP:"From this formula

$$E = m_o c^2 \tag{11}$$

we can deduce that, considering a particle at rest, mass(m_o) and energy(E) are essentially similar, that is, they are only expressions of the same thing. The mass of a body is not a constant, but varies as its energy varies"[39].

So, once again Einstein clarifies and points out beyond any doubt, but with the exception of "preconceived minds"[40], that not only when it is in motion, but also when it is at rest, P possesses its own mass! And instead, it is commonly believed that P should be massless.

In fact, according to the mathematical formalism of some equations of the Gauge Symmetry Theories (GST) or, more simply, gauge theories [41], the addition of a mass would break the gauge symmetry, making these equations vain, inconsistent and meaningless. It follows, inevitably, the assumption, as a dogma, that "in an invariant gauge theory, all the particles should have zero mass like the photon"[42].

Gauge Symmetry Theories

As is well known, with the Theory of General Relativity it emerges indisputably that the *invariance of physical laws* (under arbitrary coordinate transformations) and the *non-exceedability of the speed of light* remove from the scene any trace of the *distant action* that characterized Newton's gravitation.

Thus, the observer at a point in space-time, *x*, is influenced only by what happens in its immediate vicinity: therefore, in its vicinity, spacetime appears flat (gravity disappears if we are in free fall like orbiting gliastronauts) and general coordinate transformations reduce to the *Lorentz Transformations* of Special Relativity.

We can see General Relativity as the Theory of the Invariance of Laws for *Lorentz transformations* that depend on the point. Particles travel the *geodesics* of space-time, so that the dynamics of gravitational forces is completely determined by Geometry.

As is also known, Maxwell's equations do not change, that is they are *invariant*, therefore Weyl believed that it was possible to extend this *invariance* to the gravitational field too, as well as to General Relativity, thus trying to unify electromagnetism and gravity [41].

Therefore, working on the theory of continuous symmetry groups (or Lie's groups) and bearing in mind the Noether theorem [43], Weyl was convinced that the Conservation Laws are related to local transformations of symmetry, which gave the generic name of Eichinvarianz or gauge invariance. In fact, eich means phase, or scale or a measure of length. So, three years after Einstein's introduction of his Theory of General Relativity, Weyl suggested a generalization in which the very notion of length became path-dependent and formulated a gauge theory to be applied to General Relativity [41].

Hence, Weyl formulates its gauge theory of the Electro-Magnetic Interactions and postulates that the invariance for local coordinate transformations also extends to the calibration of physical lengths:

$$dx \rightarrow e^{\lambda(x)}\, dx \tag{12}$$

with λ (wave length) real function of the coordinates. Eq.(12) shows that the scale factor, λ(x), or gauge factor, is determined by the coefficients of a differential form, Aμ(x).

As Penrose reminds us, in Weyl's theory *null cones* retain the fundamental role they play in Einstein theory (they define the boundary velocities for massive particles and give us the local *Lorentz group* that must act in the vicinity of each point), so that a Lorentzian metric (eg, + − − −) *g* is still locally required in order to define these cones. There are, however, some additional structures to this structure of *null cone* (that is to say the *conformal* structure), and precisely a *gauge connection* - that Weyl introduced so that its *curvature* was Maxwell's tensor *F*(i.e. F_{ab}). This curvature measures the discrepancy of the clocks' rhythms[44].

However, Einstein immediately replied that the laws of Physics are *not invariant* under *gauge transformations* and that the Weyl's *gauge theory* was in conflict with Relativity Theory. In fact, "when Einstein learned about *gauge theory*, he informed Weyl that he had a fundamental objection from a physical point of view. Spectral frequencies, for example, are not affected at all by the *history of an atom*, as predicted by Weyl's theory. And, even more fundamentally, Weyl's theory conflicts with the necessarily exact identity between particles of the same type.

There is, in particular, a direct relationship between clock rhythms and particle masses. A particle with rest mass *m* has a natural frequency mc^2h^{-1}, where *h* is Planck's constant and *c* is the speed of light. In this way, in Weyl geometry, not only the rhythms of clocks but also the *mass* of a particle would depend on its history. Consequently two protons with different histories would almost certainly have different masses, according to Weyl's theory. This would violate another quantum principle, namely that all particles of the same type must be *exactly* identical.

Einstein's objection to Weyl's original *gauge idea* was in fact based on the fact that the mass of a particle, and therefore its natural frequency, is directly measurable, so that it cannot be used as a *gauge field* in the required sense. We will find that this issue is being *tarnished* in some modern uses of the idea of *gauge*"[44].

In other words, "According to Weyl's theory, the way a clock measures time does not depend solely on its current position, but also on the previously positions. Likewise, the emission frequencies of a hydrogen atom will depend both on its current and past positions. It is like saying: the behavior of the atom will depend on its history, despite contradicting experimental evidence. However, Weyl's *gauge idea* contained a fatal mistake, which Einstein clearly saw from the beginning"[45] and, as Maiani writes,"Einstein explained that the laws of physics are *not invariant* under *gauge transformations* and the elegant electromagnetic field theory had to be abandoned"[42].

In fact, Einstein had shown that the mathematical formalism introduced by Weyl was excessively *incoherent* and *incongruous*, as well as blatantly clashing with the experimental evidence. Thus, Mathematics supported by Weyl belied and contradicted the basic principles of the Theory of Relativity. It was really unacceptable for Einstein [26].

Pauli also was in full disagreement with the Weyl's *gauge theory* and immediately he wrote: "In Weyl's theory we continuously work with the intensity of the field within the electron. However, for a physicist, the latter is defined as a force acting on a test field, and since there are no test bodies smaller than an electron, the notion of an electric field internality in a mathematical point appears to be an empty function, with no content. It would be preferable to reaffirm that in physics we must introduce only quantities that are observable in principle. Thus: would we not be completely off track if we pursued a theory of continuum within the electron?"[46].

To this purpose, Sparzani specifies: "The Mathematics used by Pauli refers to the tensor calculation developed by Gregorio Ricci Curbastro and his pupil Tullio Levi Civita. It is the same mathematical formalism suggested to Einstein by Marcel Grossmann. However, modern textbooks use a more general and abstract context, that of the theory of differential varieties, in which some passages and formulations are more direct.

On the contrary, the calculations elaborated by Pauli are rarely found in the most modern manuals"[47].

Furthermore, Penrose adds:"Noether's theorem shows various limitations in the case of Gravitational Theory: when gravity is included, there must be the *gauge invariance* appropriate to gravity, i.e. the *invariance* with respect to the coordinates, using the mathematical formalism of *tensors*"[44].

Still on the subject of *Weyl's gauge theory*, Penrose wonders:"What is the geometric nature of the *bundle* on which the *gauge connection* acts? It is appropriate to think that the *bundle* is the *vector bundle* of the possible values of the *complex field* (Ψ) in each point, where the freedom of phase (*gauge*) multiplication makes the bundle *an U*(1) *bundle* on the *M*'space-time (Minkowski's curved space). In order for this to make sense, Ψ must be a *complex field* whose physical interpretation is, in a certain sense appropriate, insensitive to substitution:

$$\Psi \mapsto e^{i\,\theta}\,\Psi \tag{13}$$

where $e^{i\theta}$ is a *complex unit number* (with θ real), expressing a *complete* phase (a rotation in the complex plane, rather than a *stretch*) and *i* is the *imaginary unit*. This *unobservable* transformation is the famous *gauge transformation* where Ψ represents the *wave function* of an electrically charged particle, such as an electron.

If the *wave function* (Ψ) describes a charged particle, then we can make *gauge transformations* of the form expressed by Eq.(13), where θ is an arbitrary real position function, allowing us to change the way the phase varies!"[44].

The condition shown in Eq.(13) is called *electromagnetic gauge transformation*, and the fact that the physical interpretation does not depend on that substitution is known as *gauge invariance*. Thus, "the *Curvature* of our *connection of bundle* is the *Maxwell* F_{ab} *field Tensor*.

This *gauge transformation*, $\Psi \mapsto e^{i\theta}\,\Psi$, is physically '**unobservable, undetectable**'"[44], so it represents, however, a remarkable demerit note on these *gauge transformations* and *gauge theories*.

Note, in fact, that the idea of *gauge connection* should depend on the existence of a symmetry (which for electromagnetism should be the symmetry $\Psi \mapsto e^{i\theta}\,\Psi$) and which,

like a *dogma*, "is supposed to be exact"[43], although "*it is not directly observable*"[44]. There is, however, no absolute *scale* for time and space measurements in the Weyl scheme.

Photon's Rest Mass (m_γ) Measured by Famous Physicists

To tell the truth, we were not the only ones who tried to calculate the possible values of the photon's rest-mass, or the values of the possible dynamic-mass carried by a single photon (P). In fact, we have been preceded over the years by a multitude of prestigious physicists.

Well, it will surprise you, it won't seem real, but it is! In fact, contrary to the commonly held belief that the P must be absolutely massless, all these eminent scientists indicated a positive, real, i.e. non-zero limit to the value of the photon rest-mass (mγ), expressed in grams (g).

In order not to go into too much detail, we will just report the results of their research, without going into the details of the specific methodologies used by each. For all the physicists we will mention, the P under study is that of the optical band [38].

Based on our knowledge, the first research on this subject dates back to 1769, with Robison, who pointed out a limit to the *photon's rest-mass* (m_γ), corresponding to $\leq 4 \cdot 10^{-40}$[g][48]. Regarding this author, it is interesting to note that "In 1769, he announced that balls with like electrical charges repel each other with a force that varies as the inverse-square of the distance between them, anticipating Coulomb's law of 1785"[49].

A few years later, in 1773, an attempt to quantify the value of the P-mass was made by Cavendish, whose famous Physics laboratories at Cambridge University are named after him. Cavendish's research revealed a limit to the *photon rest mass*, m_γ , of 10^{-40}[g][50]. Some ten years later, Coulomb tried this and came to the conclusion that the value of m_γ should correspond to $\sim 10^{-39}$[g][51], i.e. a result roughly superimposable on those of Cavendish and Robison [38].

Just a century after Cavendish, it was the turn of Maxwell, whose research revealed that *photon rest-mass* would correspond to the value of 10^{-41}[g][52]. Then we have the careful tests carried out in 1936 by Plimpton and Lawton, from which a *photon rest mass* corresponding to $3.4 \cdot 10^{-44}$[g] results [53].

About 30 years later, Cochran and Franken tried this, according to whom the possible *photon rest mass* would correspond to $3 \cdot 10^{-45}$grams[54].

Bartlett's *team* came to rather similar results in 1970, whose research showed a *photon rest mass* (m_γ) of $3 \cdot 10^{-46}$[g][55].

The following year, Williams' *team* found values for m_γ corresponding to $1.6 \cdot 10^{-47}$[g][56].

Subsequently, research by Crandall (1983) showed a *photon rest mass* $\leq 8 \cdot 10^{-48}$[g][57].

In turn, in 1985, Ryan's *team* showed values of m_γ roughly corresponding to 10^{-42}[g][58].

In the same year, Fulcher found values that were slightly different from these, but completely the same as those found in the research carried out by Williams' *team*, i.e. $1.6 \cdot 10^{-47}$[g][59].

Our Measurement of Photon's Rest Mass (m_γ)

Thus, in the case of a P at the *inertial state*, that is when it interacts with another particle, so it stops running, at least for that infinitesimal moment it will oscillate much less. We will never be able to know with *accuracy* how much an interacting P can oscillate, that is what could be the number (n) of oscillations[c⁄s] in that moment.

Let's indicate this unknown value with 10^n[c⁄s],which is an *uncertainty factor*. Therefore P stops running when hitting another particle, as it happens during a *measurement* process, so it will not oscillate as when it was running, though it never stops running completely: it is the Heisenberg Uncertainty Principle to deny it, since in this case we would know simultaneously the *position* and the *momentum* of the particle, that is, two *complementary parameters* [19]. Thus, it is the Quantum Mechanics to avoid a P with $v = 0$, since a P which does not oscillate is a motionless P, and in this case we would know simultaneously *two complementary parameters* of the same particle: its position and *momentum*.

Hence, also in the inertial state, the oscillating frequency(v) of P can never be 0, but always ≥1⁄s, that is ≥ one oscillation per second (if not even ½ oscillation per second, or a fraction of its) [60].

In this regard, let us consider Eq.(11), $E=m_o c^2$, which expresses the Mass-Energy Equivalence Principle (MEEP).

Let's now apply Eq.(11) to the P, keeping in mind that one of the three parameters is well known, that is c, the speed of light in *vacuum*, corresponding to 299792.458 (±0.4) Km/sec. The 2nd parameter, E, is the *energy* of the P, which is described by Eq.(1), $E=h\,v$, where h is the Planck's constant, corresponding to $6.626 \cdot 10^{-27}$[$erg \cdot \sec$] and v indicates the frequency of oscillation (10^n) of the P considered, where n indicates the number of oscillations per second[c/s][38].

Therefore, if we want to consider the *energy* of the P in its *inertial state*, indicated with E_γ, we should have:

$$E_\gamma = h \cdot v = h \cdot 10^n \text{ [c/s]} \tag{14}$$

$$E_\gamma = 6.626 \cdot 10^{-27} \text{ [erg} \cdot \text{s]} \cdot 10^n \text{ [c/s]} \tag{15}$$

$$E_\gamma = 6.626 \cdot 10^{-27+n} \text{ [erg]} \tag{16}$$

As the *erg*, according with Planck [1], is expressed in [g·cm/s²·cm], that is in [g·cm²/s²], we have:

$$E_\gamma = 6.626 \cdot 10^{-27+n} \text{ [g} \cdot \text{cm}^2/\text{s}^2\text{]} \tag{17}$$

This should be the *energy* value of a P at an *inert state*. Hence, from Eq.(9) we can easily calculate the 3rd parameter, the *equivalent rest-mass* or *equivalent inertial mass* (m_γ) of the P:

$$m_\gamma = \frac{E_\gamma}{c^2} = \frac{6.626 \cdot 10^{-27+n}\ [\mathrm{g}\cdot\frac{\mathrm{cm}^2}{s^2}]}{(2.9979 \cdot 10^{10})^2\ [cm/s]^2} \tag{18}$$

$$m_\gamma = \frac{6.626 \cdot 10^{-27+n}}{(2.9979)^2} \cdot 10^{-20} \cdot \frac{[\mathrm{g}\cdot\frac{\mathrm{cm}^2}{s^2}]}{\cdot\frac{\mathrm{cm}^2}{s^2}} \tag{19}$$

$$m_\gamma = \frac{6.626}{(2.9979)^2} \cdot 10^{-27-20+n} \cdot \left[\mathrm{g}\cdot\frac{\mathrm{cm}^2}{s^2}\right] \cdot \frac{s^2}{cm^2} \tag{20}$$

$$m_\gamma = \frac{6.626}{(2.9979)^2} \cdot 10^{-47+n}\ [\mathrm{g}] \tag{21}$$

and we have:

$$m_\gamma = 7.372 \cdot 10^{-48+\,n}\ [\mathrm{g}] \tag{22}$$

What we get is that the *inertial mass,* or *rest mass* of the P corresponds to 10^{-48+n} grams. Hence, if the value of *n* was 10^0, that is one oscillation per second, m_γ would be 10^{-48}[g]. Whereas if *n* was 10^3 oscillation per second, we would have $m_\gamma = 10^{-45}$[g]. Of course in all cases it is an extremely small value, but it is $\neq 0$, in agreement with Quantum Mechanics, i.e. according to Uncertainty Principle[19], and just in compliance with the *Zero Point Energy*[61], *Zero Point Mass*[62] and *Zero Point Motion*[61]. That is, the *minimum* possible values, but still $\neq 0$!

In this respect, in truth, it seems very interesting to highlight, and with some satisfaction, that our P *rest mass* measurements, obtained exclusively through mathematical formalism, show positive values (though infinitesimal, as was to be expected), rather than null, as the prevailing scientific orientation would instead expect.

Furthermore, our results, as Eq.(22) shows, do not differ from those performed by excellent physicists; on the contrary, in some cases they are even superimposable. We are referring, in fact, to the measurements carried out by the *teams* of Williams and Fulcher's ($m_\gamma = 1.6 \cdot 10^{-47}$[g]), or those found by Crandall: $m_\gamma \leq 8 \cdot 10^{-48}$[g]. Well, the latter is really completely superimposable on our measurement: they match perfectly!

Nor can we fail to mention that even one of the founding fathers of Quantum Mechanics, Louis de Broglie, did not agree with the concept of the photon (P) without the slightest mass; a concept that was nevertheless indispensable for making *gauge theory* equations congruent, and which was spreading widely in the scientific community.

On the contrary, de Broglie was convinced that P, like any other particle, was provided with its own *intrinsic mass*, as well as a *rest mass*, which in our opinion should correspond to the value of *h*, the natural constant, which Planck expressed precisely in *erg*, how to say in grams[1]. As is known, in fact, dimensionally, the *erg* is equivalent to $1\mathrm{g}\cdot\mathrm{cm}^2/\mathrm{s}^2$.

Therefore de Broglie was involved in measuring the *rest mass* of the photon(m_γ), and as we read from de Broglie: "m_γ could not exceed 10^{-48} [g]"[63].

Well, once again, unlike the massless P, clearly positive values emerge, which authoritatively and prestigiously deny that the m_γ can be equal to 0!

Furthermore, with great satisfaction and emotion, we note that the calculations and results developed by de Broglie are also entirely corresponding and superposable to our own measurements!

Finally, one cannot overlook what emerges in this regard from Penrose's masterful volume, 'The Road to Reality', in which he writes: '**The mass of the photon**, if not 0, **should be <10^{-20} electronic masses**, **for good observational motives**"[44].

As it is known, the mass of the electron is $9.1\text{-}10^{-28}$ grams, so if the photon (P) is <10^{-20} electronic masses, we have: $9.1\cdot10^{-28-20}$[g]. Thus, in agreement with Sir Roger Penrose, a P which is not massless must have a mass very close to < $9.1\cdot10^{-48}$[g].

Penrose's calculations, among the greatest living mathematicians (and Nobel Prize in Physics, 2020), are completely superimposable on ours: $7.372\cdot10^{-48}$ [g], as shown in Eq.(22). This is of great honour for us and greatly comforts us.

DISCUSSION

In summary, we have two different scientific orientations, clearly opposed and, unfortunately, irreconcilable:

1) on the one hand, widely supported by the scientific community, there is that of the supporters of *Gauge Symmetry Theories*(GST), according to which P, like any other particle, absolutely *must* be massless, since, if it were equipped with an *intrinsic mass*, **a massive P would break the symmetry**, inducing a *spontaneous symmetry breaking*(SSB), and ruining the equations inherent in gauge theories, and thus making such theories incompatible and unsustainable.
2) On the other hand, the fundamental point of reference is represented by Einstein's *Mass-Energy Equivalence Principle* (MEEP). According to this *principle*, as is known, any particle with energy must correspond to an *equivalent mass*, and vice versa. Therefore, since P is a particle known to have its own energy, that energy must unequivocally correspond to an *equivalent mass*! So, a positive mass value, ≠ 0!

In other words, still for the MEEP, to an "energetic" particle, carrying energy, forces etc., should correspond a *mass equivalent* to the energy carried, divided c^2. Since, according to Chandrasekhar, and based on *Zero Point Energy*(*ZPE*) [61], no particle with zero energy can exist. In other words, there should not be any particle carrying energy, with a zero mass[64].

To this purpose, Feynman says:"*energy and mass* differ just for a c^2 factor, which is merely a question of units, so we can say **energy *is* the mass**. Instead of having to write the c^2, **we put *E=m* "**[7].

Well, not accepting the mathematical result, simple, linear and elementary, as well as very elegant, emerging from the MEEP, means wanting to undermine the validity of the most famous equation in the world!

And with what courage?! And that, just so as not to invalidate the mathematical formalism built to support GST. No, it is not possible, it cannot be accepted passively.

In short, we have two completely contrasting mathematical formalisms, polar opposites, in clear conflict with each other, so they cannot coexist, not even conceptually.

Therefore, since one cancels out the other, either the equations underlying the GST are valid, consistent, and congruent, but consequently making the MEEP equation mathematically invalid, or vice versa! And how would the MEEP be invalidated?

Well, as is known, Einstein applied the MEEP first of all to light, to his *quantum of light* [5], so that, if in the equation $E=m\cdot c^2$ the value of the mass, m, were equal to 0, we would have:

$$E= 0\cdot c^2 \quad (23)$$

In that case, the very most basic Mathematics tells us that any physical or mathematical system, or any value numeric that is multiplied by 0 will cancel out, that is, it will also become equal to 0. Therefore we will have:

$$E = 0 \quad (24)$$

Ultimately we have that the value of the energy (E) of P also cancels out! That is, Eq.(24) tells us that a massless P will have to be equally *energyless*, so not only would not be able to emit electromagnetic energy, to radiate light, but would even be devoid of its same energy (E): it is as if it never existed and, therefore, we should all live in an eternally dark world. In fact, we would never have appeared in this world!

Well, to everyone's comfort, the teachings of Chandrasekhar may be useful in this regard: “According to a fundamental consequence of the quantum nature of the matter, **the lowest energy possible for a system cannot be null, that is zero**, but it needs to have a value different from zero: it is called *Zero Point Energy*”(*ZPE*)[61].

Furthermore, from Planck's formula $E=hv$, shown by Eq.(1), also known as “the Planck's Radiation Law”[4], we deduce that if the value of E were equal to 0, as shown by Eq.(24), indicating a massless P, a *natural value*, such as Planck constant (h), would also cancel out, resulting in 0.

But no, it's not possible! We all know that h is a natural constant, with its own well-known *intrinsic mass* value, exactly equal to $6{,}626\cdot10^{-27}$[erg·sec].

So, taking things into account, it was possible to find, unfortunately, that by applying the mathematical concepts of GST (in which it is essential that P is massless) to Einstein's MEEP, the values of the MEEP equation cancel out, they reset to zero. And not only that! It follows, in fact, that an *energy less* value of the P, in turn, goes to zero, that is, to also cancel the Planck's Radiation Law, normally expressed by Eq.(1).

In other words, two of the most important equations in all of Physics, which have found wide application and confirmation operational in many natural and experimental phenomena, would be completely invalidated if, in line with GST, if the P were massless.

So, there are two things: either the equations inherent in these two fundamental pillars of Physics are wrong, or there is a setting error in the mathematical formalism applied to GST.

Well, in our opinion, following the path of logical and deductive reasoning, in the manner of ancient Greek thinkers, it is much more probable and plausible to deduce that error, a *forcing*, is present in the mathematical approach to the equations of GST.

Moreover, we have already been able to observe and highlight that the application of the mathematical concepts of GST to *Perturbative Calculus*[26], or to *Quantum Field Theories*, such as *Quantum Electro-Dynamics*(QED), generates the well-known *divergences*, i.e. *zeroes* or *infinities*[65]. E.g, the *gauge field*, which mediates the interaction between the charged spin - ½ fields, is the Electro-Magnetic Field (EMF). The spinorial QED, or

QED Lagrangian (L_{QED}), for a spin - ½ field interacting with the EMF, is represented as follows:

$$L_{QED} = -\frac{1}{4} F^{\mu\nu} F_{\mu\nu} + \bar{\psi} (1/2\, i\, \partial - M + e\, \not{A})\, \psi \qquad (25)$$

where ψ and its antiparticle($\bar{\psi}$) are the fields that represent charged particles (Dirac spinors: e.g. electron–positron field); *i* is the imaginary unity; M indicates the mass of the electron or positron; *e* is the coupling constant, equal to the electric charge of the 2-spinor field; $\not{A}$ is the covariant four-potential of the EMF generated by the electron itself; $F_{\mu\nu}$ is the *EMF tensor*, which represents the evolution of the free field, that is in the absence of additional potentials.

Basically, Eq.(25) describes the interactions between a quantized material spinorial field (i.e. the electronic field) and, in agreement with GST, a non-massive vector field that describes the EM radiation, i.e. the EMF managed by the photons(Ps), considered massless. So it is obvious that, as the most basic rules of arithmetic teach us, any number, or physical system, multiplied by 0, will always give us a result of 0, or, divided by 0, it will give us infinity (∞).

Just so we explain, among other things, the well-known *divergences* that systematically emerge from QED, Perturbative Calculus, or Yang-Mills theories.

Yet, as we have already described in previous works[66], it would be enough to insert, in the equations where the *divergences* emerge, the value of the *momentum* (***p***) of an optical P, equal to $\boldsymbol{p} = 1.325 \cdot 10^{-22}$ [g·cm/s] as shown by Eq.(8), substituting it for the massless value of the Ps: all the *divergences* will disappear instantly, as if by magic![26].

In short, the conceptual foundations of GST are based on the need that any elementary particle, and so P, must be exclusively massless, in order to satisfy the GST' equations, since a massive particle *breaks their symmetry*.

However, various mathematicians consider the basic assumptions of the *gauge theories* to be wrong, as well as *in conflict with the experimental evidences* and in clear disagreement with the facts, *distorting the physical reality itself* [26].

Moreover, as Penrose reminds us, "these GST are *mathematically inconsistent*, adopting a mathematical structure somewhat complicated and arbitrary, which does not satisfy the strong demands for coherence"[44].

To this purpose, indeed, weakest point of GST, in our opinion, consists in imposing that all the particles must be free of an intrinsic mass.

In fact, the downside of the GST lies in the fact, really paradoxical from a *logical* point of view, that the introduction of a simple mass parameter, necessary to describe the *intrinsic mass of a particle*, is in contradiction with the existence of this symmetry: it is said, that is, that *the mass breaks the gauge symmetry*, and inducing the so-called *spontaneous symmetry breaking*(SSB).

In this regard, Witten expresses himself as follows: "This proposal of the spontaneous breaking (SB) of electro-weak symmetry(EWS), or SSB, though simple and refutable with known facts, probably does not tell us the whole story" [67].

Instead, returning to Einstein's MEEP, Penrose's words come to mind: “The famous formula, taken from Einstin's Special Relativity, $E= mc^2$, tells us that **mass (*m)* and energy (*E*) are interchangeable**.

For example, when an uranium atom decays, splitting into smaller pieces, the total mass of each of these pieces, if they could be restored to rest, would be *less* than the original mass of the uranium atom; but if we take into account the *energy of motion* (*Kinetic Energy*) of each piece, we actually find that the total is *unchanged*. In fact, mass is conserved”[4].

Therefore, we believe it is necessary to underline that the phenomenon described by Penrose, which occurs continuously in reality, clearly highlights that in the processes of transformation of mass into energy (and vice versa) there is full conservation of mass (and thus of energy), in total compliance with the Laws of Conservation of Mass and Energy, and in accordance with the MEEP formula. Obviously, this applies to physical systems, atoms, and elementary particles, whatever particle is considered, including the photon(P).

Moreover, in our comfort, we read from Penrose:"Maxwell electromagnetic field delivers energy. For $E=mc^2$, it must also have a mass. Maxwell's electromagnetic field is therefore also matter! Now we must certainly accept this notion, since the Maxwell's field has an intimate involvement in the forces that bind particles together.

The mass of anybody must receive a significant contribution from the magnetic fields within it"[4]. It is pleonastic to specify that Maxwell's electromagnetic field(EMF) is constituted and operated by *Planck's grains*, by Ps!

In sum, it really seems a contradiction to continue to support the common concept that P is massless. This denies the reality of the facts and the multiple evidence, even experimental, of the numerous mechanical effects induced by light! And, as physics students know well, Mechanics implies *mass*. The main subject, the 1st actor in all mechanical phenomena is mass!

Analysing a lot of physic phenomena, happening more or less ordinarily, it seems that sometimes the P, rather than a particle made merely by energy, behaves like a particle incorporating a certain *hiden* mass, though infinitesimal, but not always insignificant, or effect less. We think that several physical phenomena, in which the P is involved, are not completely explainable only with the energy of the P, but they make us think that the P under its energetic *shape*, hides a mass too. A mass which we cannot see when the P shows us its wave-like aspect, that is, when it is in motion [35].

In fact, in agreement with Bohr Complementarity Principle[15], only when the P stops travelling as a wave, it can show us its *corpuscular aspect*, and in that occasion we can hope to detect the probable mass of the P (maybe not directly, that is observing its *mass effects*).

In this regard, let's consider just two of the most well-known light-induced mechanical phenomena: the photo-electric effect (PEE) and the Compton effect (CE).

As it is known, the PEE is the emission of electrons from a material when light shines on it. The first to talk about the mechanism at the bottom of PEE was Hertz, back in 1887: he had observed that the energy of the light can be transformed in *mechanic* or electric

energy. Moreover, he had noticed that a metal pushed by UV rays, got a positive charge, with a later emission of a flux of electricity from the irradiated metal[68].

It was Thomson, in 1897, to show that this flux was made of “cathod rays”; in fact, he deduced that the ejected particles, which he called corpuscles, were of the same nature as cathode rays: these particles were *electrons*[69].

To this purpose, in 1902, Lenard observed that the energy of individual emitted electrons was strictly dependent on the *energy* conveyed by the single “*electromagnetic radiation(EMR) quanta*”[1], and completely independent of their intensity [22].

But this was in contradiction with the knowledge of the time, since the kinetic energy freed by the flux of electrons coming from the metal did not depend on the intensity of the EMR incident: in open contrast with the only wave-like interpretation of the light. In fact, this appeared to be at odds with *Maxwell's wave theory of light*, which predicted that the electron energy would be proportional to the *intensity* of the radiation.

The PEE was explained by Einstein as evidence of light's particle nature: electrons are ejected only when the light's frequency is sufficiently high. This is because light is composed of *light’s quanta* and each of them must have enough energy (above a certain "work function" for the material) to knock an electron loose [5].

It is fundamental that the *quantum of light*, or *Planck grain*, have a frequency higher or equal to a certain value (threshold level or cut level), which changes slightly as the target changes. The PEE is performed only when the energy carried by the *EMR quantum* is the same or higher than the energy relating the electron to the nucleon (*Binding Energy*). That is, if the *EMR quantum* carries an enough power to push away the electron from the atom, just as a billiard small ball thrown with the right energy, it pushes away the opponent ball [35]. It could be a suitable example, since the *kinetic energy* of the small ball is given 100% to the pushed ball[12].

But if we give an insufficient energy to the ball which will at the most lay down on the ball, without moving it, or if we use a lighter ball, an empty one for instance, and we throw it with vigour, against the opponent ball, we will notice that it does not move, it stays where it is. It happens the same with EM waves (EMWs): if we strike the target metal with lower frequency waves, such as radio waves, the PEE will not take place. Why?

The answer is that the radio waves do not have enough *energy*, in fact they are beneath the *threshold level*.

But the PEE is a phenomenon of “corpuscles”[5] more than of waves. That is a *light quantum*, as to say a photon(P), which manages to push away an electron from the metal, seems more a mechanic effect, that is a mass effect of the P, namely a “*push effect*”, to quote Feynman [7], rather than a merely *energetic effect*. In other words the Ps involved in the PEE behave like ultramicroscopic small balls (having probably a tiny mass), rather than as waves. In agreement with Feynman, indeed, “the photons carry *angular momentum* like spinning rifle bullets”[7].

But the *momentum* ($\vec{p}$), indicated by Eq.(2), is given by $\boldsymbol{p}=m\mathbf{v}$ [9], where $\mathbf{v}$ is the speed and m is the mass of the analysed particle. Hence, we should not be far from the truth if we infer that in the PEE a mass is subtended.

Besides, Newton *docet*, a particle to which is correlated a *momentum*, should also convey, or at least *hide*, a mass. Thus, the PEE seems more a "material" phenomenon, handled by corpuscles.

Yet, while P also has its own *momentum*, it is nevertheless still argued that P is massless! As is known, another very obvious action of a purely mechanical nature, carried out by photons(Ps), takes place in the so-called *Compton Effect* (CE)[21], of which we report Heisenberg's interesting description:"When X-rays arrive in a *Wilson Chamber*, it sometimes happens that they release an electron(*recoil* electron) in a molecule of the gas of the chamber, which is made visible by its fog wire. This phenomenon can be interpreted by assuming that the EMR(in our case X-rays) consists of individual corpuscles, which **collide** against the gas molecules (Einstein's *light quantum* hypothesis). Each *light's quantum* must therefore be assigned a certain energy *E* and a certain *momentum* ***p***, which are related to the frequency *v* of the radiation by the relations $E = h \cdot v$ and $\lambda = h / p$"[70].

Indeed, it was precisely this typical mechanical effect induced by X-rays, this *collision* of the P with the electron (a collision *sufficient* to detach the electron from the atom) that made the scientific community definitively accept the corpuscular nature of Ps. In fact, Heisenberg points out: "The application of **the mechanical collision laws to the interaction between *quantum of light* and electron** now provides in an elementary way a relation between the direction of recoil of the collided electron and the direction in which the scattered *quantum* recedes. Compton and Simon's experiment ([71]) allows direct verification of the consequences of this purely corpuscular theory of *X-quanta* scattering.

Indeed, **Compton and Simon's results were thus able to demonstrate with certainty** that the laws of *elastic collisions* are fulfilled and thereby directly highlight **the corpuscular nature of electro-magnetic radiation**''[70].

In short, the CE would have never been possible with the only wave-like hypothesis of the light: it confirms clearly the existence of also a corpuscular behaviour of the EMR, at least those travelling with a certain *frequency*. We have seen, therefore, that Ps show the same behaviour as particles, as quantum objects carrying, presumably, an infinitely small mass, but still different from 0. In effect, the Quantum Mechanics confirms that Ps are particle, corpuscles: they behave like not deformable balls when they are stroked, with infinitesimal dimensions (as happens with the CE), or they are absorbed or emitted, still entire, when they interact with electrons orbiting around an atomic nucleus[38].

Well, it is truly astonishing that in the face of this evidence and many other mechanical phenomena activated or induced by light, by Ps, we can equally continue to assert that EMR does not transport the slightest mass, or at least something similar, conveyed for example by the *dynamic energy* , or E_{Kin} , with which the P travels.

Obviously one could object: it is the same energy of the Ps that does all this. Maybe, but always having to admit that with its energy, to explain the various mechanical actions, the P also vehicles a mass value, such as, for example, an *energy-mass density*.

Yet, it would be enough to keep in mind that, as stated in the Bohr Complementarity Principle[15], the presumable mass transported by P in motion can never be shown or detected; it will be necessary for its travel to stop, that is, when P interacts with matter: just for that very brief moment, in which P puts away the wave-like clothing and puts on the corpuscular habit, it will finally be able to show, always *indirectly*, the effects exerted

by its *hidden* mass, manifesting the well-known various mechanical phenomena induced by light!

In this regard,to better understand, and partly justify the possible objections, it is interesting to keep in mind what Penrose writes: "In effect, **mass(*m*) is conserved, but being composed, in part, of energy, today it seems to be less clearly the measure of real substance**"[4].

In other words, the same mass is also, if not essentially, composed of energy, highly concentrated!

Likewise, the considerable mass conveyed by the two Ps generated by the decay of the π^o meson, as described by Penrose [4], cannot be denied at all. Indeed, such massive Ps, spontaneously generated in nature, can represent one of the most significant and valid *physical and mathematical proofs* of the real existence of *non-zero mass Ps*; useful proofs, moreover, for the purposes of a correct construction of the *postulates* (and theorems), according to the Euclidean rules[38].

Feynman adds: "**Even light**, which has an energy, **has a mass**"[7]. And what is this mass? Just by inserting *Planck's formula*($E=h\,v$) into the MEEP($m=E/c^2$), shown by Eq.(9), the mass (m_γ) carried by any P should correspond to:

$$m_\gamma = \frac{h\,v}{c^2} \tag{26}$$

where the parameter *v*, obviously, indicates the oscillation frequency of the P taken into consideration.

More specifically, based on our calculations, a common P of the optical band, caught in full motion, as Eq.(8) shows, should carry a mass (m_γ) related to its *momentum*(***p***), i.e. an *hidden dynamic-mass* equal to $1.325\cdot10^{-22}$ [*g*·cm/s].

Instead, if a P is studied in its *inertial state*, its *rest mass* (m_o) should correspond approximately to $7.372\cdot10^{-48+n}$ [g], as shown by Eq.(22), where the parameter *n*, i.e. 10^n, indicates the oscillation frequency of the P; frequency which, even in a P at its *minimum energy* instant, or *rest energy*, it can never be completely equal to zero, as if to say without the slightest oscillation: no! Heisenberg's Uncertainty Principle (HUP)[19] categorically prohibits this, since we would have, simultaneously, an accurate knowledge of two *complementary parameters*. And even the so-called *Zero Point Motion* principle (ZPM) forbids it[61], since, always by virtue of the HUP, of the same subatomic particle, or quantum object(QO), we cannot know its *momentum* (Δ_p) and position (Δ_x) simultaneously[62].

Finally, another piece of evidence, both experimental and frankly natural, closely inherent in the fields of Kinematics, Electrodynamics and Photodynamics, which blatantly denies that P must at all costs be devoid of even the slightest mass, is described in a Seminar held by Madame Mariotti. In fact, regarding the fact that when light travels through a medium other than *vacuum,* it slows down its speed significantly (in water, it loses about 1/3 of its speed), it is worth mentioning a very witty observation and physical explanation from Mariotti. She says: "In relativistic *quantum mechanics* every particle is associated with a field and vice versa. The photon is the particle (messenger or "particle force") associated with electromagnetic radiation(EMR). The **photon is massless by definition**"[72].

Well, this last quote, shared by most of the scientific community, seems very weak to us, since it is stated precisely as a *dogma*, that is, without a clear physical explanation, as well as being in total conflict with Einstein's MEEP!

In our opinion, in fact, continuing to consider that the photon(P) is massless, just "by definition", without justifying this statement in a physical, real sense, is in full conflict even with the simplest, most accessible and orthodox scientific methodology: the Galilean method.

In this regard, in truth, Feynman's teachings come to mind: "Finally, we shall mention certain things whose rest mass m_o is zero. A photon(P) of light, for example. A P is like a particle, in that it carries an energy and a *momentum*. The energy of a P is a certain constant, called Planck's constant, times the frequency of the P: $E=hv$. Such a P also carries a *momentum*, and the *momentum* of a P (or of any other particle, in fact) is h divided by the wavelength: $\boldsymbol{p}=h/\lambda$.

But, for a P, there is a definite relationship between the frequency and the wavelength: $v=c/\lambda$. Thus, we see immediately that the energy of a P must be the *momentum* times c, or if c =1, *the* ***energy and momentum are equal***. That is to say, **the rest mass is zero**. Let us look at that again: **that is quite curious**.

If it is a particle of zero rest mass, what happens when it stops? *It never stops!* It always goes at the speed c.

The usual formula for energy is $m_o / \sqrt{1-v^2}$. Now can we say that m_o = 0 and v = 1, so the energy is 0?"[7], just as would be evident from Eq.(24) if the mass of P were equal to 0. But it can't be like that!

And in fact, to the question he himself asked himself, Feynman answers: "We *cannot* say that the energy is zero"[7].

So, if even a particle like P *cannot* have an energy value of zero, likewise, in full respect of Einstein's *Mass-Energy Equivalence Principle* (MEEP), P *cannot* even have a mass value of zero.

And instead, followers of *gauge symmetry theories*(GST) argue the opposite. According to these concepts, also adopted by the Standard Model, no particle, including P, can ever be endowed with its own intrinsic mass, since even the smallest mass value, inserted into their equations, *breaks the symmetry*, and thus invalidates these equations and the entire framework of GST! It is believed that a remedy for *Spontaneous Symmetry Breaking*(SSB) would have been found through the Brout-Englert-Higgs Mechanism[73],[74], but continuing to leave the P and gluon(G) massless[26].

However, various physicists and mathematicians, some even prestigious ones, were perplexed and doubtful about it. For example, Penrose writes: "**I question the reality of the *spontaneous symmetry breaking* (SSB)**! There are various difficulties in this **idea of SSB**…Already at a temperature of $\leq 10^{16}$ Kelvin degrees(°K), and at $\approx 10^{-12}$ seconds after the Big Bang, the photon and W and Z bosons were *frozen* by the SSB process, so only photon remains massless, while the others gain mass. Maybe it is the Higgs Boson to give masse to these particles, as well as to itself and quarks. And how? **Really great and ingenious ideas**!"[44].

In short, following the description of the Standard Model, we find that the *electroweak symmetry breaking* (EWSB) is totally asymmetric, since the SSB (related to the "phase transition" triggered by the lowering of the temperature of the primordial Universe) alters also the symmetry of the *Higgs field*(HF). That is, the EWSB means that only the W and Z° bosons acquire mass, while photon(P) and gluon(G) will remain massless forever!

Why do we have such a dichotomous and asymmetric behavior, in a model based primarily on symmetries?

According to Standard Model, the more a particle interacts with the HF, the greater its mass.

The P and G, on the other hand, do not interact with the HF at all, so these particles will remain massless. But how is it possible to state it with such a determination?

Based on what preexisting phenomenon, or assumption? How is it possible to confirm and prove this particular behavior of the HF in favor of some particles, compared to others, closely related?[65].

Why can't we apply the mathematical formalism used in favor of the bosons W and Z °[73],[74],[75] to P and G too? Well, if for the considered massless P one can also discuss, as done so far, on the contrary, even considering the G as a massless particle, it lays bare in their entirety all the contradictions and inconsistencies emerging from *gauge symmetry theories*(GST). And why?

Because, as we all know, G is the messenger particle, or boson, of Strong Nuclear Interaction(SI) which, precisely, operates in the narrow range of an atomic nucleus, or a nucleon, and not for greater distances.

In fact, even in the case of other GST, such as the *Yang-Mills theories*, Yang and Mills[76], and so many A.A., knew that the bosons of a Nuclear Force cannot, for any reason, be massless: in this case their range of action would extend to infinity!

Therefore, we think that even the zero mass attributed to G is patently incongruous and inconsistent: it is in full discordance with MEEP and, therefore, with the simplest and most basic concepts of Arithmetic.

In this regard, moreover, we read from Mariotti: "the 3 quarks that make up a proton are responsible for only '1% of its mass: the rest comes from the interaction between quarks and Gs"[72], as to say from Strong Interaction(SI), and whose boson is the G, operating in this case inside the internucleonic spaces.

In short, contrary to the notions spread through GST, and shared by the majority of the scientific community, from Mariotti's CERN Lectures we learn that G would not be a massless particle at all, but rather as heavy as 99% of the mass of a proton, that is, a good $1.655874 \cdot 10^{-24}$ grams. More than massless G!

Among other things, similarly to the consequences that a massless P could induce, the massless G would deny also one of the basic principles of Special Relativity, the MEEP: $E=mc^2$. To this purpose, indeed, a massless G implies an energyless G! In fact, considering the G's mass as zero, we would have: $E=0 \cdot c^2$, and thus E=0.

As to say that the boson of a nuclear force, the SI, considered the most energetic boson, is massless and energyless, where the bosons of the other nuclear force, the Weak Interaction(WI), are highly massive![26].

It is really against the reality of the facts: the MEEP categorically forbids that the G can be massless: in that case, ex abrupto, its energy (which is enormous) would instantly vanish. In other words, anyone who claims that G is massless affirms at the same time that the most famous equation in the world is not true, but is misleading, wrong[26].

In addition, a G massless is in open and unacceptable contrast with the Yukawa Principle[77], according to which the mass (*m*) of the boson carrying a *fundamental force* must absolutely be inversely proportional to the range(*R*) of the force it conveys:

$$R = \frac{h}{2\pi\, mc} \tag{27}$$

where *h* is the Planck's constant and *c* is the speed of light in the vacuum.

In this regard, in fact, the bosons of the other *nuclear force*, the WI, which should have a *range* roughly superimposable on that of the SI boson, have a very limited range. As our calculations show, "the upper limit of their range corresponds to $1.543 \cdot 10^{-15}$[cm] for particles W^+ and W^- and $1.36 \cdot 10^{-15}$[cm] for Z° particle"[78].

In short, continuing to support gauge theories consequently means undermining the mathematical formalism of Einstein's MEEP: an equation that even the man in the street knows, printed on an infinite number of T-shirts!

Can it ever be true that such an equation is wrong, or incongruous, or unresponsive to physical reality?

On the other hand, either the MEEP of Special Relativity is incorrect, or the equations referring to GST are incongruous, and specifically those equations incorporating massless values attributed to P, and therefore cause of *divergences* (i.e. the well-known *zeroes* or *infinities* emerging as results of these equations)[66].

And it is certainly not a note of merit in favor of the mathematical formalism developed for GST.

Indeed, such *divergences* show precisely the weakest and most compromising point of such theories.

In this regard, in his book entitled 'QED', Feynman writes: "It is impossible to prove the internal coherence of Quantum Electro-Dynamics(QED). It is, in fact, surprising that this *coherence* is still undemonstrated.

What is certain is that we do not have a good mathematic basis to formulate QED theory"[37]. So, it's like saying that Feynman's words represent a prestigious *endorsement* in support and in favor of our dubious orientation about the mathematical validity of GST. As we know, in fact, QED also falls within the GST.

Moreover, it is interesting to highlight that these GST, already developed since 1918[41], were completely dribbled and ignored by Yukawa, who was trying to draw an identikit, with relative mass and radius of action, of the possible boson of the so-called *Majorana-Heisenberg's Exchange Forces* (*EF*) [79],[80],[81] whose most represented

mathematical formalism had been elaborated by Majorana just a few days after the discovery of the neutron by Chadwick[82], but published only in 1933.

In fact, as Madame Fermi writes, “Majorana had thought out Heisenberg’s theory of the nucleus with protons and neutrons as building stones before Heisenberg published it, but he never wrote it”[83].

As is known, these *EF* were hypothesized in order to understand how protons (and neutrons) remained stably together, in the very narrow space of an atomic nucleus, overriding the intense Coulomb repulsive forces. It was therefore to be a very strong force, acting inside the atomic nucleus, that is, a Strong Nuclear Force, or Strong Interaction(SI), which exerted an attractive action between nucleons, through the continuous and mutual exchange of a particle: a so-called *exchange boson*, and thus promoting the stability of atomic nuclei [84].

Going into more detail, we read: “In comparing Majorana's nuclear model with Heisenberg's, it is commonly argued that Majorana modifies the shape of the Heisenberg exchange force. Attention!

The change is much more drastic. The Heisenberg nucleus is not held together by *EF*, which can even be repulsive, but by a very cumbersome complex of various forces, which includes an attractive force between neutrons, analogous to the polarization forces of atomic physics.

Majorana's hypotheses are very simple and natural. Majorana's exchange force alone holds nucleons together in the atomic nucleus.

In reality, it would be more appropriate to clearly distinguish the two models. Heisenberg's great merit is that he has shown that a model is possible that ensures nuclear stability by introducing only protons and neutrons, which interact with forces that can be described within ordinary quantum mechanics.

Majorana's merit was to have identified the shape of the *exchange force*, attractive, which under minimal assumptions ensures nuclear stability. Furthermore, Majorana's formulation immediately allows us to interpret the exchange force as a low-energy limit of a quantum field theory interaction between nucleons and the pion system, as later shown by Yukawa in 1935”[85].

Taking advantage of these various intuitions, in fact, Yukawa develops a theory that therefore predicts the existence of a new particle, unstable, and with a very short half-life, and which (in total antithesis with GST) must have a mass hundreds of times greater than that of the electron, given the very narrow range in which this boson must operate. We thus arrive at spin-zero pseudoscalar pions[77].

Therefore, Yukawa gives no practical, real and *physical* meaning to the supposed ideological and mathematical contents of GST, according to which, as with the photon(P), also the boson of the other *nuclear force*, the SI (whose radius of action, which, as Fermi establishes, can never go beyond the radius of an atomic nucleus [86]), must absolutely be a massless particle: otherwise the *symmetry is broken*.

So, rather than getting lost in the controversial concepts of Mathematics built for GST, Yukawa realized that he had to follow logic, evidence and concreteness, so he could never accept the criteria of a mathematical approach which, in order not to be soundly

denied, it still imposes today, like a *dogma*, like a *conditio sine qua non*, that even the boson of a nuclear force must be massless.

It follows, obviously, that a massless gluon(G), e.g., contrary to current scientific knowledge and acquisition, should have an infinite range of action, therefore up to the limits of the Universe, and if anything beyond!

But this is an unacceptable and clearly incorrect concept, so much so that Enrico Fermi writes: "*Nuclear Forces* are of this nature that they can only act if the two particles are very close (and, when I say very close, I mean at a distance of the order of magnitude of 10^{-13}cm, that is, at a distance one hundred thousand times smaller than the radius of the atom, which is of the order of 10^{-8}cm); in a word **nuclear forces are forces of short range**"[86].

Nonetheless, there continues to be a claim that all particles must be devoid of intrinsic mass, a concept still pursued by many supporters of GST, and which, as a mockery of fate, is clearly denied, even mathematically, as well as categorically denied and forbidden, by one of the GST: the well-known Quantum Field Theory(QFT).

According to QFT a particle generates a field, and the field acts on another particle. In this regard, Fermi specifies: "Consider two particles, a proton and a neutron e.g., rather close to each other: each of them surrounds itself with its field, which will have to act on the other. Get sourrounded by its field means emit *quanta* of this field" [86]. The quanta of action of the field are said bosons.

Thus, in agreement with Quantum Mechanics(QM) and QFT, the higher the value of the mass of a particle, i.e. the more the energy(Δ_E) taken from the field, the sooner(Δ_t) the energy must be returned to the field itself [87].

This is an inviolable rule of QM, dictated by the Heisemberg Uncertainty Principle(HUP) [19]:

$$\Delta_E \cdot \Delta_t \geq h \tag{28}$$

where h is Planck's constant, equal to $6.626 \cdot 10^{-27}$[erg · sec]. Applying the HUP to the boson of a *nuclear force*, we have that the Δ_E of Eq.(28) corresponds to the energy value of the considered boson. If we have information about this value(Δ_E), what we do not know, in this case, is the value of Δ_t , that is, the lifetime(t) of the boson, before it returns to the field all the energy(E) taken, so to speak, borrowed.

The duration(t) of this energy loan, in favor of the boson considered, is provided by Eq.(28), from which we have:

$$t = \frac{h}{E} \tag{29}$$

Moreover, Eq.(29) shows that *time* and *energy* are inversely proportional. That's why the higher the energy value borrowed, as saying subtracted from the field, the sooner this energy must be returned.

Now, we take into account the MEEP: $E=mc^2$. Thus, by replacing the value of E in Eq.(29) with that of MEEP, we obtain:

$$t = \frac{h}{mc^2} \tag{30}$$

Eq.(30), as Fermi reminds us "it indicates the time(t) in which the boson issued may remain in free space. If then it is assumed that its speed is the maximum speed at which a particle can move, that is the speed of light (c), it is seen that the maximum distance(d) it can reach, before being recalled to weld the debt, is given, as order of magnitude, by the product of time(t) for the maximum rate at which the particle can move"[86], namely:

$$d = t\ c \tag{31}$$

So, we put in Eq.(31) the value of t expressed by Eq.(30):

$$d = \frac{h}{mc^2} \cdot c \tag{32}$$

$$\text{namely: } d = \frac{h}{mc} \tag{33}$$

Thus, the maximum distance the boson can take is the one expressed by Eq.(33), i.e. the upper limit of its range.

Bearing in mind that quarks and gluons(G) had not yet been hypothesized at the time of Fermi, so π mesons were thought to be the only bosons in SI, we read: "In the 20 years since the founding of the AIP (American Institute of Physics) to the present, Nuclear Physics has made perhaps faster progress than any other branch of our science.

Twenty years ago, the neutron had not yet been discovered…According to Yukawa's theory, every now and then a neutron transforms into a proton plus a π meson; the latter is then reabsorbed, reemitted, reabsorbed again, and so on. The nuclear field associated with this oscillation will extend around the neutron to the maximum distance achievable by the π mesons continuously emitted by the nucleon. And how far can they go? Let's see it.

A meson has considerable mass, and to make a meson that can be so fun to dribble with, you need to have an amount of energy equal to the mass of the meson multiplied by the square of the speed of light, c"[88].

Well, as is clear, Fermi also doesn't take into account the GST criteria at all, according to which all particles *absolutely* must be massless!

Fermi continues: "Who pays for all this energy? Well, no one; but then, if no one pays, you have to resort to a loan.

Now, there is a very special rule in the 'energy bank', namely: the bigger the loan, the closer its deadline is.

In quantitative terms, this banking practice is represented by one of the possible forms of the Heisenberg Uncertainty relation. One can borrow a quantity of energy, W, for a time, t, of the order of Planck's constant, h, divided by the same W; therefore, the maturity, t, of the debt will be h/mc^2. The meson will be able to move away from its source, but not beyond a distance(d) equal to t multiplied by the speed of light c (see Eq.31).

According to this mechanism, therefore, the range of action of nuclear forces is, substantially, h/mc (see Eq.33), and is inversely proportional to the mass. For the interaction to be short-range, the **quanta of the field mediating the nuclear forces must have a very high mass**"[88].

Nonetheless, according to supporters of GST, the Strong Interaction (SI) boson, operating exclusively in the same spaces in which the WI operates, is considered massless! Then why did they accept this *compromise*?

Because the mathematical formalism of *gauge invariance* is used, i.e. a formalism in which the mass of particles tilts the equations: the mass *breaks the symmetry*. Subsequently, in order to deal with the problems, the GST require that all the particles are massless[26].

Then, since 1964, with the invention of the BEH-*Mechanism* and the alleged Higgs Field, various particles can acquire mass by reacting with this field, but not all: only those sensitive to WI. Therefore the gluon(G), being sensitive to the SI, but not to the WI, remains massless! Ed anche il fotone(P) è insensibile alla WI, per cui anche il P è massless[89].

Ultimately, there are two things, and there is no escape: either there are errors in the setup underlying the mathematical formalism on which GST are built, as highlighted by Einstein and (as reported above) confirmed, for example, by Pauli and Feynman, or the MEEP is incorrect.

It's clear in fact that, in accordance with the most elementary arithmetic principles and rules, and as Eq.(9) shows, by inserting a massless P into the MEEP, the latter is inexorably zeroed even on the energy side, *sending to cards forty-eight* an equation confirmed experimentally an infinity of times. No, it can't be.

Indeed, if we reflect carefully, with any massless particle, and as P and G are considered, one could not at all set up, nor write the MEEP equation, since Eq.(9) should be written like this: $E/c^2=0$. But no, it's impossible, paradoxical!

To this purpose, Feynman specifies: "This theory of *equivalence of mass and energy* has been beautifully verified by experiments in which matter is annihilated—converted totally to energy: An electron and a positron come together at rest, each with a *rest mass* m_o. When they come together they disintegrate and two gamma rays emerge, each with measured energy of m_oc^2. **This experiment fornishes a direct determination of the *energy* associated with the existence of the *rest mass* of a particle**"[7].

It is very important to underline that in this experiment two massive particles transformed into two gamma rays, say two gamma photons(γPs), each carrying the *dynamic mass*, in agreement with Feynan represented by "$\boldsymbol{m_oc^2}$ "[7], and equivalent to the energy of a moving electron.

In essence, and it is of considerable significance to highlight this again, Feynman described, without a shadow of a doubt, that in nature massive Ps are habitually and currently created, each carrying a mass of as much as 0.511 MeV: and we are still discussing massless Ps![38].

In short, what Feynman says coincides entirely with the concepts that underlie the possible *postulate* proposed with this article. In support of this and, in agreement with Feynman, Penrose says: "The famous formula, taken from Einstin's Special Relativity, $E=mc^2$, tells us that **mass(*m*) and energy(*E*) are interchangeable**. For example, when a uranium atom decays, splitting into smaller pieces, the total mass of each of these pieces, if they could be restored to rest, would be *less* than the original mass of the uranium atom; but **if we take into account the energy of motion (Kinetic Energy) of each piece, we**

actually find that the total is unchanged. Indeed, mass (*m*) is conserved, but being composed, in part, of energy, today it seems to be less clearly the measure of real substance"[4].

Therefore, we believe it is necessary to underline that the phenomenon described by Penrose, which occurs continuously in reality, clearly highlights that in the processes of transformation of mass into energy (and vice versa) there is full *conservation of mass* (and thus of *energy*), in total compliance with the *formula* of Einstein's MEEP. Obviously, this applies to physical systems, atoms, and elementary particles, whatever particle is considered, including the photon(P). Furthermore, it acquires particular importance that, as just described by Penrose**, in the energy of motion of each particle, or *Kinetic Energy*, the mass is conserved** [4].

Well, Penrose's words represent a prestigious confirmation of what we support with this article, namely that even a photon(P), which, when in motion is represented by its *momentum*(***p***), and with this *Kinetic Energy* also carries a *dynamic- mass*, but of which, being in motion, we cannot have no information.

Penrose adds: "To give a surprising example, where the effect of Einstein's mass-energy relation ($E= mc^2$) is present in an extreme form, consider the decay of a subatomic particle, the π^o meson. It is a *material particle*, with a well-defined (positive) mass. After about 10^{-16} seconds it almost always disintegrates into just *two photons*. For an observer at rest with respect to the π^o meson, each photon takes away half the energy and, in fact, half the mass of the π^o meson. Yet this 'mass' of the photon is of the most impalpable kind: pure energy"[4].

So it is surprising, logically, to assume that a particle like the π^o meson, "weighing the equivalent of 135 MeV"[90], splits into two photons(Ps), even in this circumstance considered equally massless!

No, it's impossible, it's also against the Law of Conservation of Mass: they will be two Ps carrying a *mass-dynamics equivalent* to 67.5 MeV each. And Yang and Penrose, two Nobel Prize winners in Physics, say so!

It can be deduced, of course, that Yang also does not take into account at all the limitations, imposed like *dogmas*, by the mathematical formalism applied to GST.

Let's read more from Mariotti:"Weak interactions are short-range: although they need "messengers" such as the photon, called $W^{\pm}$ and Z, their mass is very large, about 100 times the mass of the proton. Why the photon mass and the masses of W and Z are so different is really difficult to understand"[72].

Yes, even Madame Mariotti seems quite perplexed and disconcerted by this zero mass attributed to the photon and proposes a solution, suggested by what continuously occurs in nature: "**A possible solution**: we know that **photons can behave like massive particles**; this happens when they travel in a medium other than empty space. The physical reason for this is that the propagation of the electric and magnetic field (i.e. the photon) interacts with the medium.

The resulting effect is **the 'slowing down' of the propagating wave**, which **is the equivalent of an effective mass for the propagating photon**"[72].

So, as Mariotti explains, we have the physical effects of the actual behaviour of the photon (P) in front of our eyes every day: they look just like the typical effects of a not massless P!

The explanations, including mathematical explanations, that are commonly given in order to justify the belief that P can never possess mass, are not at all convincing from a physical, nor logical point of view! On the contrary, a completely massless P should not slow down at all in water, glass, or other media with *refraction index*, $n_o > 1$.

Thus, although considered as a massless object**, *kinematically*** the **P behaves like a real and *massive* particle**, capable of inducing various well-known phenomena of a clearly mechanical nature, such as the *photo-electric effect* (PEE), Compton and Raman effects, etc..[38].

Feynman points out: 'Newton thought that light was made of particles, which he called *corpuscles*, and he was right. Today we know that the light (meaning all the electromagnetic waves) is made of particles, because if we take a very sensitive tool, making a clicking when hit by the light, if we make the light dimmer, the intensity of every single click remains unchanged: they are just less frequent. Light is made of photons. We use the photomultiplier to detect a single photon. When the photon hits a small plate it causes the emission of an electron from one of the atoms of the plate''[37].

Hence, this shows the assumed *mechanical effect* determined even by a single photon(P), and able to hit a motionless electron and move it away [91]. Yet, the P is considered massless.

CONCLUSIONS

At this point, one wonders: how can a particle, without the least mass, have the same effect of a billiard small ball which hits and moves away the opposing ball? The latter is certainly bigger than the small ball, just as the electron compared to the P. It seems more likely that it is a body having a mass to move the electron from the metallic plate: it would be like saying that the P transports also a mass (a mass *equivalent to the energy* transported)[24].

In this regard we read: “One of the central discoveries of physics is the observation that gravitational mass and inertial mass are identical. Which was not entirely clear at first, since the two masses are defined completely differently.

Nature also knows about massless objects, that is, light particles, the so-called photons. To these, however, one can associate a mass, based on Einstein's formula $E = mc^2$, since they possess an energy that is not equal to zero”[92].

Therefore, since P, an energetic particle, can also be associated with a mass, an *equivalent mass* to be exact (Einstein's MEEP *docet*), from the point of view of Mathematics it can easily be deduced that this mass, or photon’s mass (m_P), is a function (f) of its energy (E_P):

$$m_P = f\,(E_P) \tag{34}$$

from which it is easily deduced that the value of the probable mass transported by the P (m_P) varies, in a ratio directly proportional to the variation of the energy(E) of the

same P, as saying that the *dependent variable* (m_P) varies in a directly proportional ratio to the varying values of the *independent variable* (E_P).

In fact, it is necessary to keep in mind that the energy of P, E_P, shown in Eq.(34), does not represent the total energy of P, but essentially its *kinetic energy*, E_{Kin} , since it does not incorporate the *rest energy* (E_o) of the P considered, since the value of this E_o represents an *invariant* value (similarly to the value of the *rest mass*, m_o, of the P in question). Well, from which is the E_{Kin} of a P represented? From its *momentum* (***p***)!

In this case, in fact, ***p*** expresses the properties of a P in motion, just as highlighted by Newton ($\vec{p}=m\cdot\vec{v}$) and expressed by Eq.(3) [9].

As is known, as set out in **&2** and **2.1**, the *momentum* parameter (***p***) was introduced by Newton in order to calculate **how much a body in *motion* weighs**. The *momentum* (***p***) of a particle, indeed, is the product of two quantities: the particle's mass and its velocity. So ***p*** indicates the P captured in its wave-like guise (as reported above, in fact, we all know that the P is also provided with its own *momentum*).

Therefore, according to the Newtonian *momentum* formula, even a particle like P should also carry a mass *equivalent* to the energy values carried, such as a *dynamic-mass* carried with ***p***, but which we can never hear about as long as P is in the running: the Bohr Complementarity Principle[15] categorically prohibits this, as shown in **&2.3**.

Let us now go and verify whether the *postulate* proposed with this work rests on solid foundations, or not.

To this end we use the quantum formula of *momentum*, that is, the one developed by de Broglie*(**p**=h/λ),* as shown by Eq.(2). This *momentum* formula, as Feynman suggests, is preferable to the Newtonian formula when operating within

Quantum Mechanics[7]. Well, in **&2.2** we calculated the *momentum* of an optic P, described with Eq.(18), and whose value, in mass, corresponds to $1.325\cdot10^{-22}$ [g·cm/s].

Therefore, if it is true, as we have postulated, that the probable P's mass is a *function* of the P's energy, we should find that Ps of different frequencies, that is, carrying different energy values, should equally carry different mass values: mass of which there will never be any trace as long as the P is in motion(Complementarity Principle *docet*).

Let's go see. We start with Ps of wavelength (λ) greater than the optical band, i.e. less energetic Ps, so we go to evaluate the relative mass values, presumably a *dynamic mass*, transported with *momentum*. So let's consider radio waves with λ equal to 10 meters, or 10^3[cm]:

$$\boldsymbol{p} = \frac{h}{\lambda} = \frac{6.626\cdot10^{-27}\ [g\cdot\frac{cm^2}{s}]}{10^3\ [cm]} \tag{35}$$

$$\boldsymbol{p} = 6.626\cdot10^{-30}\ [g\cdot\frac{cm}{s}] \tag{36}$$

Well, comparing Eq.(36) with (8), it can be seen that a radio wave, 10 metres long, shows a *momentum* (***p***) carrying mass values equal to a good 8 orders of magnitude less than that carried by an optical P. These results fully confirm the *postulate* proposed with this article.

We do the same operations, but with electromagnetic radiation(EMRs) more energetic than light radiation, that is, with shorter wavelengths(λ). Therefore, we consider an X photon(XP) having λ equal to 0.1nanometers, or 10^{-8}[cm]:

$$\boldsymbol{p} = \frac{6.626 \cdot 10^{-27}[g \cdot \frac{cm^2}{s}]}{10^{-8}[cm]} \tag{37}$$

$$\boldsymbol{p} = 6.626 \cdot 10^{-19}\,[g \cdot \frac{cm}{s}] \tag{38}$$

Therefore, comparing Eq.(38) with (8), even in this circumstance it is clearly detected, confirming the proposed *postulate*, that the *momentum* of an X-ray, having a λ 3 orders of magnitude lower than the λ of visible light, equally carries mass values equal to 3 orders of magnitude greater than that conveyed by a P of the optical band.

Now let's consider EMRs with an even shorter λ (therefore more energetic EMRs), equal to 10^{-12}[cm], i.e. corresponding to photons in the gamma band (γPs):

$$\boldsymbol{p} = \frac{6.626 \cdot 10^{-27}[g \cdot \frac{cm^2}{s}]}{10^{-12}[cm]} \tag{39}$$

$$\boldsymbol{p} = 6.626 \cdot 10^{-15}\,[g \cdot \frac{cm}{s}] \tag{40}$$

Even in this case, as can be easily seen by comparing Eqs.(40) and (8), it turns out that a highly energetic P such as a γP travels with a *momentum* (***p***) clearly different from that relating to the optical P, so much so that it conveys a *dynamic mass* (related to the value of ***p***, in our opinion) of a good 13 orders of magnitude greater than visible light.

These are the facts, from which it would be deduced that the *postulate* proposed with this article can be valid, or plausible.

In this regard, moreover, Franco Pacini's words come to mind:"It must be taken into account that already in Restricted Relativity the categorical distinction between **matter** and **movement**, typical of Classical Mechanics, disappears.

The distinction essentially falls because it turns out that the energy associated with *motion*, namely *Kinetic Energy* (E_{Kin}), is endowed with the most important of the characteristics of matter: *inertia*.

This follows from the famous relation $E=mc^2$, where *E* is a quantity of energy, *m* the mass it represents, *c* the speed of light. It can be said that **motion is itself matter**, and a complete description of matter must include that of its *motion*"[93].

Well, this very important and fundamental concept expressed by Pacini, in total agreement with Penrose[4], is also in support and in perfect assonance with what we maintain: that is, that the *momentum*(***p***) of P, a particle still considered massless in all respects, transports, together with the E_{Kin} of P, also matter, presumably in the form of *mass-energy density*, *inertia*, *mass density of matter*.

However, since ***p*** expresses only the properties and characteristics of when a particle is in motion, that is, when P shows only and exclusively its wave-like appearance, in this circumstance the Bohr Complementarity Principle[15] will not allow us any information on the possible corpuscular appearance and behavior of P, either directly or indirectly, that is, through the mechanical actions performed by the P (massless!). In this regard, moreover, from Feynman's teachings we learned that: **"The *momentum* is a mechanical quantity"**[7].

Pacini continues: “To describe the matter present at every point in space, together with the characteristics of its *movement*, one must resort to a set of coefficients, T^{ik}, whose values will vary from point to point in space and over time. This set of coefficients is known as the *Energy Tensor*”[93].

Regarding this same *Tensor*, indicated by Penrose with the parameter T_{ab} , we read: “We could expect that the appropriate relativistic generalization of Newton's theory would be one in which an equation related the Curbastro Ricci Tensor of spacetime to a *tensor* quantity that appropriately measured the *mass density of matter*. This last quantity is what is designated as the *Energy-Momentum Tensor*, and its family of components is normally written: T_{ab} . One of these components measures the *mass-energy density*; the others measure the *density of momentum*, stresses and pressures in the material”[94].

Moreover, analyzing the last six equations, it clearly emerges that, by increasing (or decreasing) the values of the *energy* (*E*) transported by the different Ps, equally, and in a precise directly proportional and consequential ratio, the value of the respective *momenta* increases (or decreases) in parallel[95], which in turn *subtend mass values* (*m*), precisely expressed by Planck in grams per centimeter per second[1]. And it is just as if these *probable mass values* attributable to the moving Ps (m_P) depended on the different energies of the Ps(E_P) considered, just like a *function*(*f*): $m_P = f\ (E_P)$. We also believe that it would be precisely these *mass values*, transported with *momentum*, that would allow those various and well-known *mechanical actions* performed by Ps.

In short, as just read by Pacini, “the E_{Kin} is endowed with the most important of the characteristics of matter: *inertia*”[93], so it is understandable, and really justifiable, that *momentum*(***p***), together with the E_{Kin} of P, can also carry, although *hidden* (by the Complementarity Principle), a sort of *mass density*, thus making even more congruent, and mathematically coherent, the proposed *postulate*.

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