Review Article

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About the structure of leptons: a review

Abstract

It is presented an interpretation on the nature of the three ‘fundamental standard model particles view so far as point like objects.’ These observables known as Leptons (electron, **e** (=**q-**), positron, **e̲** (=**q+**), neutrino (=*ν*), and antineutrino, ν̲). For convenience the discussion is focused on the **e**. Where the relativistic invariant **q-** is the negative charge of the **e**. The discussion show that a consistent view of any lepton is its constitution by entangled field. In the case of ‘**q**’ the electromagnetic field, i.e. photon(s) and in the case of the neutrino the short-lived neutral current (Z). Although these two type of currents are extremely different we argue for the equivalence on their role on the lepton nature.

Keywords: leptons, physics, electromagnetism, speed of light

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Introduction

Central unknowns about the leptons include their size, the dual particle-wave behavior among the most mysterious issues about their nature and the basis for the rise of Quantum Mechanics (Schroedinger/ Heisenberg) as a fundamental theory of the physics in same footing with classical mechanics (Newton/Poincare), the universal law of gravitation (Newton/Einstein) and electromagnetism (Maxwell/ Heavyside).

It is our purpose to address the above key unknowns of size and dual wave particle nature of the leptons. Section 2 presents the hypotheses we propose on the nature of leptons, in detail by addressing the case of the electron (charge q negative, $q = -\sqrt{(2\alpha)}.\sqrt{(\varepsilon_0\hbar c)}$, where fine-structure constant is α*,* the electric permeability of the vacuum is ε_0 , $\hbar$ is the Plank constant and *c* the speed of light in vacuum). Section 3 discuss the arguments to the simplified analysis performed. Section 4 presents required refinements to the basics of the ideas put forward before. The mathematical consistence of the proposed model is addressed in Section 5. Conclusions are presented in Section 6.

Section 2

Using the hypothesis that a lepton constitutes a twist of the propagating field, ad-minimum it is needed to make full use of the Lorentz expressions from start:

$$Ct' = \gamma(ct - \beta x) \quad (1)$$

$$x' = \gamma(x - \beta tc) \quad (2)$$

$$y' = y \quad (3)$$

$$z' = z \quad (4)$$

Which are valid for a rectilinear uniform motion, with β = v/c and $1/\gamma = \sqrt{(1 - \beta^2)}$. The expression of the energy, i.e. the Hamiltonian reduced to H = *hc*, when we consider that the rest mass (m_0) of the photon is zero. But there is a need for better transformation because:

The above expressions are too simple for our requirements because: 1st) v = c and Lorentz transformations Equation 1.a implies that the time in the frame moving with the photon, t’ stopped, while location stays unchanged, and all this makes no sense. 2nd) the transformation fails to be useful to our purposes because it is thought for objects for which we are allow to neglect a dimension. The paper deals with the dimension of the lepton rendering the transformation useless. 3rd) this is further explained here: because the model assumed the twist takes place in the propagation of the signal modulation, i.e. the photon, a twist requires at least a limited extension and change in the orientation of the structure. For an example of a graphic description of Lorentz transformation allowing the consistent representation of an object with a finite extension see e.g. Figure 2.[1] Observable measurement of twist in the light caused by the presence of external **B**- field is observed in the laboratory.[2]

In this work it is proposed the lepton has spin ½ due to entanglement and in particular the electron is just the electromagnetic field displacing at the observed c velocity in vacuum and of an energy (the electron E = 511 keV) such that stability exist for the particle in an structure that we simplify to the essential entanglement feature of being a Möbius strip with

$$\boldsymbol{v} = c\,\mathbf{e}_x \quad (5)$$

$$B = \mathrm{Re}(Be^{i(2\pi x/\lambda - \nu t)})\mathrm{e}_y \quad (6)$$

$$E = \mathrm{Im}(Ee^{i(2\pi x/\lambda - \nu t)})\mathrm{e}_z \quad (7)$$

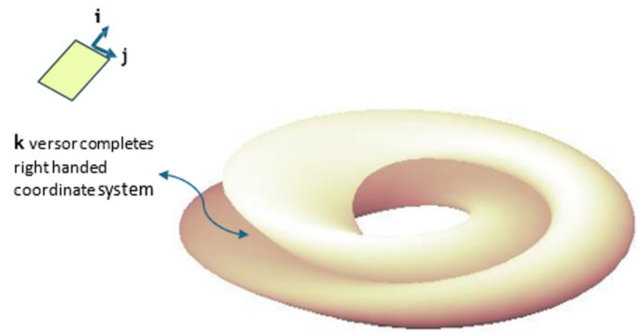


Figure 1 example of proposed entangle internal lepton structure ($l/\sqrt{3} > w$ for view purpose).

The upper left handed inset illustrates in a piece of the Möbius strip orientation of the coordinate system used where by definition we use a right-handed coordinate system an employ versors $\mathbf{i} = \mathbf{e}_x$, $\mathbf{j} = \mathbf{e}_y$, $\mathbf{k} = \mathbf{e}_z$, on the equations. (For clarity we use one name or the other of same versors’ set.)

Equation 5 gives the direction propagation the electromagnetic wave (**EM**-wve with frequency ‘*ν*’). For a stable, i.e., constructive length $l = c\nu$, *to* which corresponds a maximal width $w = l/\sqrt{3}$. In this case the normal to the surface superpose positively provided observed at distances a few times larger than l.

The model satisfies observation that from the center of the Möbius strip emanates **E** field as it is known for the '**e**' or constitutes a sink of the **E** field in the case of its antiparticle (positron) as it is agreed to interpret. By design the angular momentum satisfies spin (½ $\hbar$) because in two turns of 360° the orientation goes back to its original values in this way distinguishing the lepton of a integer angular momentum particle as it is the case of e.g. the photon. **B**-field becomes very small through the fast near-cancelation generated in the superposition due to many turns the **EM**-wve perform during measurement time of the charge of the electron. Simultaneously the outgoing **E**-field is observed to apparently point out covering all of space within the fastest time measurement 3 up to date possible of 10^{-20}s.

The positron would be the same description but a reversed orientation of the electromagnetic field present in the Möbius. Regarding the neutrino the field to be considered is the very heavy and short-lived boson Z, see e.g. theory of **Z boson** decays.[3]

This neutrino and antineutrino assumption is observationally valid for neutrinos with energy below those needed to create both weak Z and Y boson particles.

Section 3

Fundamentals of the evaluation

Evaluation of the charge energy density

$u = (8\pi)^{-1}[E\text{-}D + B\text{-}H]$ (8)

Here we assume the vacuum properties for the internal fields in the entangled region it is confined as defined above (A möbius strip structure of a minimal width $w = \ell/1.73205$ constrained to generate its charge.) Then the constitutive relations of the medium implies:

$$D = \epsilon_0 E \quad (9)$$

$$B = \mu_0 H \quad (10)$$

Then we reduce the number of fields to:

$$u = (8\pi)^{-1}[D^2/\epsilon_0 + \mu_0 H^2] \text{ or} \quad (11)$$

$$u = (8\pi)^{-1}[\epsilon_0 E^2 + 1/\mu_0 B^2] \quad (12)$$

For an electromagnetic pla**n**ar wave function, where the Maxwell equations used is:

$$rotorE + \partial_t B = 0 \quad (13)$$

Which gives

$$|B|^2 = (\lambda/\mathrm{v})^2 \mathrm{E}^2 \quad (14)$$

Where here we consider

$$\mathrm{E} = e_z E \cos(2\pi \mathrm{x}/\lambda - 2\pi t\mathrm{v} + \varphi_{\mathrm{E}}) \; and \quad (15)$$

$$\mathrm{B} = e_y B \sin(2\pi \mathrm{x}/\lambda - 2\pi t\mathrm{v} + \varphi_{\mathrm{E}}) \quad (16)$$

Hence we obtain

$$u = (8\mu)^{-1}[\epsilon_0 \mathrm{E}^2 + (\lambda/v)^2 \mathrm{E}^2/\mu_0] \quad (17)$$

It is $u = (8\mu)^{-1}[\epsilon_0 + (\lambda/v)^2 \mathrm{E}^2/\mu_0]\mathrm{E}^2$ (18)

$$mean(u) = (8\mu)^{-1}[\epsilon_0 + (\lambda/v)^2 \mathrm{E}^2/\mu_0]\mathrm{mean}(\mathrm{E}^2) \quad (19)$$

We reached in this way to fundamental expressions for the behavior of the internal **EM**-field for the electron or positron but the outcome for the field expressions of Equations 15 and 16 would cancel by the many turns in 10^{-45} seconds with no production of radial charge and refinement of the model is then required. It is in the following Section 4 where we attempt just that.

Required refinement of the model

The above planar wave simple assumptions for the **EM**-wve cannot produce the proposed conditions for this classical model of the lepton. Then here we proceed to refine the nature of the considered **EM**-wve. For this purpose we consider an interval τ corresponding to a complete circuit at the void speed of light of the Möbius strip in the longitudinal direction 'x', phase is constant at $\ell/\lambda = \tau\mathrm{v}$, *hence* $\ell = \lambda\tau\mathrm{v}$, with Electromagnetic energy of the '**e**' is 8.19×10^{-14} joule or about 0.511 Mev. And we can write the

$$\lambda = c\tau = ch/(\mathrm{vh}) \quad (20)$$

Hence

$$\ell = 2\pi Energy(e) \quad (21)$$

$$ch = 2\pi 0.511\mathrm{MeV}c/h \quad (22)$$

$$= 2 * 3.141592 * 8.1910^{-14} Joule 2.99710^{8} ms^{-1} / (6.6260701510^{-34} JouleHertz^{-1}) \quad (23)$$

Taking the observational identification of the size of the electron, through the observation hydrogen atom it is acceptable to consider a common size of the proton of 2.8179 10^{-15}meter. This means that for orbital cycle of the wave have about 1045turns, an order of magnitude in time 1025 times faster than the shortest measurement possible, see the British news agency in its BBC-report, 2020,[4] implying a superposition of the wave function with a net out-pointing **E**-field, as it is possible to find mathematically in Section 15 of J.D. Jackson.[5] Hence, this information is here used to find the mean intensity of the superposed **E** -field which will match the charge of the '**e**' = 1.602 176 634 10^{-19} Coulomb.[6]

The anomalous **B**-field of the '**e**' is much smaller due to destructive superposition, with an observed value of (the electron magnetic moment, or more specifically the electron magnetic dipole moment, is the magnetic moment of an electron resulting from its intrinsic properties of spin and electric charge. The value of the electron magnetic moment (symbol μ_e) is

$-9.2847646917\ (29)\times10^{-24}\ \mathrm{J{\cdot}T^{-1}}$) (24)

Finally the localization of the fields are expressed by the step function along coordinate 'y' in the strip, limiting the presence of **E**(x, t) and **B**(x, t) to

$$-w/2 < y < w/2 \quad (25)$$

By the step function. Because the fields are defined by the Möbius strip, the extension in the z-direction of the fields is given by $\delta(z)$.

Which is consider in this case for simplicity.

In Möbius strip coordinates:

Ex-field = 0 for $-\infty < y < -w/2$

$E_x - field = E_0 |\mathrm{Re}e^{-\mathrm{x}[2\pi x/\lambda - \omega t]}|$ for $-w/2 < y < w/2$, and (26)

E_x-field = 0 for $w/2 < y < \infty$ (27)

For the **B**-field we have similar considerations with component along y as we define in the Möbius strip (Figure 1).

For the case of a common size of the '**e**' of about 10^{-13}m we obtain for the external observation generated by the charge as

$$4\pi q_e = Area\, \mathrm{E}'\mathrm{n}_{\mathrm{Area}} \quad (28)$$

In this case, using Gauss law, we extract the measured

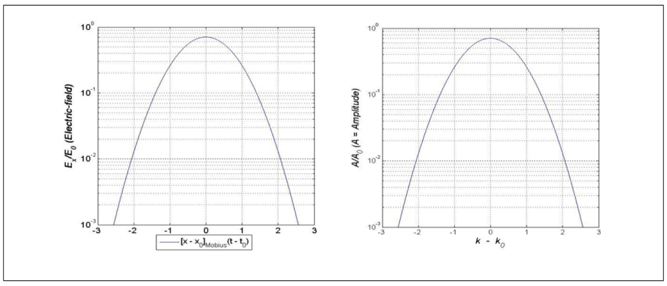
E_r-field = q_e/r^2 (29)

Where the radius of the atomic '**e**' is used, i.e. r = 10^{-13}m. This information in the 3- dimensional space directly provides us the approximate amplitude E_0 of the internal **E**-field simplified above together with **B**-field constituting the internal structure of the electron in its definition limited to an assumed extension with

$\ell = \sqrt{3}\,w$

Were sqrt√3 = 1. 7320502S … (Figure 2)

Figure 2 The considered view of the E-field in our analysis, and its train of amplitude intensities assuming a simple Gaussian-distribution.



Cosidering q_e = 1.602 176 634 10^{-19} Coulomb we obtain

E_z = 1.602 176 634 10^{-19} Cb /(10^{-26}/m^2) (30)

In Möbius strip, which provides an energy density:

$$mean(u) = (8\pi)^{-1}[\epsilon_0 + (\lambda / \mathrm{v})^2 / \mu_0]\mathrm{mean}(\mathrm{E}^2) \quad (31)$$

$$mean(u) = (8\pi)^{-1}[\epsilon_0 + (\lambda / v)^2 / \mu_0]mean(E_z^2) \quad (32)$$

With $\lambda = c\ \ \tau = ch / (\mathrm{vh})$ (33)

And in the Appendix the fitting numerical values for the correct description of fundamental properties like charge and energy of the electron are evaluated and consistency with observation is checked.

A further simplification, and reduction of border problems to the above proposed model having **E** and **B** fields represented as short threshold (up and down step) of width *w* functions is their approximation with a Gaussian as illustrated in the Figures 2.a and 2.b where we have quantitative values for both the fields and the combination of contributing terms of an infinite expansion where as it is known dominate the first 5 or 4 frequencies in the solution considered (Left side of Figure 2, i.e. Figure 2.b).

A internal EM-wve structure as alternative to the dual particle-wave 'e' view

A slowly moving '**e**' reaching the surface of any conductor material and also semiconductor will sense the presence of unbalanced charges at the surface, and the more long-range but weaker magnetic field which the model explains is accompanied with decreasing the density of energy as the lepton enlarges as particle in the scale deduced for the internal energy (see Section 4/Appendix). This effect will generate for a collimated train of electrons which pass a slit on a far surface the Fraunhofer diffraction effect well understood for waves, but not so much for a point-like lepton in the current literature. In consequence the common outcome is addressing it as a solely quantum mechanics dual behavior of small particles, including molecules as a particle – wave property beyond classical mechanics.

Classical mechanics is otherwise well suited for the description of waves for of a variety of fluids, also the electromagnetic field5. The classical observation of the diffraction of the electron of charge **e** is granted in this model view by the fact of its **EM-wve** structure.

Dominant amplitudes to the **E**-field we limited to A0 ± 2 σ_{AO} with a contribution of ~ 90 % of the intensity of the **E**-field (Figure 2.b). Then the energy is E0 ±E for a range

$$\lambda_0 - 2\sigma < \lambda < \lambda_0 + 2\sigma \ = \ (\mathrm{v}\pm\Delta\mathrm{v})\mathrm{c} \quad (34)$$

When following the proposed Gaussian **EM-wve** we consider $\ell = 10^{-5}(\lambda_0 \pm 2\sigma)$ it is achieved the wished condition of ~ $\mathbf{E}_0$-field, a steady field as proposed above. This is different of the wave train package as proposed e.g. in p. 210, Section 7,[5] which correspond to a changing field which would not represent the steady negative charge of the electron. A more precise approximation here to the cut in the Amplitude expansion terms could be its description by a generalized Lorentzian/Kappa function.[7]

Diffraction requirements

On the variable wave particle behavior of the electron/proton; in our Ansatz that the nature of the lepton of charge **q** being by nature **EM**-field (of a twisted specific nature) the occurrence of diffraction associated to the length (i.e. size) of the structure can be described in the following paragraphs.

For a simple observation of diffraction, it is required the collimation of the light or well collimated light or particle beam to take place. Intensity of the beam helps to fasten the process of registration of the diffraction effect.

Here we consider the usual case of **two slits** located as illustrated in Figures 3a & 3b.

The low energy lepton beam approach to the thin wall showing two slits at distances as follow(here we follow Ref[8] 'Faynman et al, Lecture for Physics Book 1, chapter 30') **EM- wave**. We can describe it as the interference pattern of two-point sources separated by '**d**' multiplied by the diffraction pattern of a slit of width ' Δ ' and used the integer '**m**' to refer to interference fringes that will produce Fraunhofer diffraction pattern at a distance '**D**' >> '**d**.'

Then we can well see that as simple collimated electromagnetic wave produce diffraction when impacting in a thin barrier with two slits, so does the steady impact of these leptons (electron or positron) given that the inner structure is here proposed to be electromagnetic waves that will find the time to interact with the currents at surface and slit, given the non- equilibrium conditions at these sharp borders of the solid barrier, preferable a conductor material.

The loss in intensity at the slit and barrier will naturally depend on both the kinetic energy the leptons arrive as well as the process or absorption and emission by the material of the impacting **EM**-field carried by the electron/positron. A loss of 50% of the intensity is common. The emission has the form of point like at each slit (Figure 3, left) with a effect on a screen located at a sufficient distance to generate the Fraunhofer pattern illustrated in the Figure 3, right.

The wave length to be considered here is the 'de Broglie' particle wave length which is defined as

$$\lambda_{dB} = h / p_{lepton} \quad (35)$$

In this case the electron. We consider a electron momentum 'pe' corresponding to a non- relativistic energy of about 10^{-4} keV which corresponds to $\lambda_{dB} \sim 10^{-9}$ m, or a picometer.

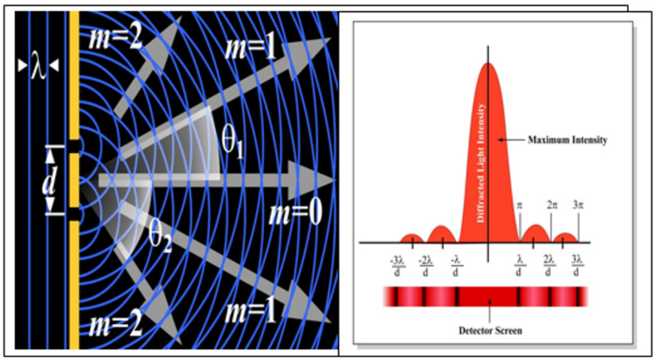


Figure 3 (left) pattern for two slits width d at distance D >> d for incoming wave λ ~ d/√3. (right) diffraction pattern far from barrier with the two slits. (For convenience the illustrating figures are taken from the instruction physics material available in the World Wide Web.).

As it is standard in the discussion of diffraction the Figure 3 uses the m = 0, 1, 2 to indicate the successive regions of constructive addition that generate pattern on the right and its relationship with the $(\lambda / v)_{dB}$ wave the leptons arrive in a wave front that is collimated. (That is not the assumed property that corresponds to the internal constitutive fields of the lepton λ, i.e., of the EM-field electron/positron internal electromagnetic wave, which has $\lambda = c^2 / (vc) = 2.4271\ 10^{-12}$ m ad $v = c/\lambda = 1.234807\ 10^{20}\ s^{-1}$ as evaluated in Section 3).

Discussion

Entanglement observed when head-on collision between leptons takes place is an inherent characteristic of the presented interpretation on the nature of the lepton and satisfies all observations. The boundary smooth decrease in in the **EM**-field at the discontinuous borders[9] of the Möbius strip deserves further study beyond the scope of this work.

Further the presented view does not require the existence of cloud of virtual positive charges as needed in some interpretation of quantum field theory assuming limit to a negligible size approaching a point-like dimension generating such intense local concentration of energy which would excite a cloud of virtual positive charges from the vacuum in the view of quantum field theory, see e.g. discussion following Equation 17.41 on the self-energy subject in Ref[5] (Jackson, 1962).

In this analysis a Möbius structure of a minimal dimension constrained its internal **E**-field to generate the '**e** charge' is used following Ref[5] In this way the density of energy analysis simplifies to the Equations 3 – 5, **Section 2**. The derivation in **Section 3** provides an internal energy density having a value 4.20 10^{-17} Joule/m^2 as constrained by observation on the charge extension in the Hydrogen atom of 10^{-13}m, its mass, spin. This value of the electron energy density $\langle u_0 \rangle$ appears correct when we consider that is about **1000^{13}** times smaller than the energy-density packed in the electron volume, which has a dimension of 1.73205 10^{-2}C m^2 and a dirac-δ(z) in the z-Möbius direction as defined above. And we here considered that Electromagnetic energy of the **e** is 8.19×10^{-14}Joule or about 0.511Mev.

Hence with the scaling with electron size of

$u = (r/r_0)^{-2}\ u_0$ (36)

$\langle u0 \rangle \approx 4.2 \times 10^{-17}$Joule/m^2 with room to be even smaller than 10^{-15}m before irradiating into pure electromagnetic energy[10–12] (two photons totaling each the energy of twice the electron mass): Entanglement properties has a first time observation reported in Ref.[13–15]

Further studies shown that occurrence in the simpler case of the head-on collision of two electrons generating two entangled photons. The ***annihilation electron-positron*** happens when an electron (e–) and a positron (e+), the antiparticle collision. The result of the collision at 'low' energies is the annihilation of the electron and of the positron, and the creation of two photons (gamma rays):

$e^- + e^+ \rightarrow \gamma + \gamma$ (37)

There is conservation of

a) Charge

b) Energy

c) Linear momentum

d) Angular momentum as well as entanglement.

The entanglement is observed in the two photons created (gamma rays). (For a basic description see e.g. **Wikipedy**) In above paragraph 'low' energies are those in which the very heavy phonons Z and Y of the weak interaction are not produced.

There are important applications to health and construction provided by these process of particle **annihilation,** see e.g. Ref [16–18]. The technique is call computed tomography.

The Fraunhofer diffraction properties connect directly to the classic view in sections 5.a, and 5.b of the variable extension (size) of the **e** allowing it to sense the two slits at orders of magnitude larger (d = O 10^{-9}m) than its atomic size radius of ~ 10-13 m. The case most studied. The limit on the slits' distance '**d,**' and slit width 'Δ' This is illustrated in Figures 3.a and 3.b. The '**e**' de Broglie wave length (λ_{dB}) is the one considered. The feature making possible the diffraction is explained by the wave internal structure of the electron interacting with the currents in the surface of the border/surface of the metal frame with slits.

The Appendix explores the model consistency with observation when undergoing a variety of dynamic processes of the assumed structure of the **e**. The corresponding physical aspects of the model of this lepton is addressed in Sections 3 to 5. In the final part of the Appendix we find arguments for conditions of the spacial-extension (the Möbius strip) supporting the lepton intrinsic **EM-wve** resisting the tearing effect caused by the model electromagnetic fields up to the highest energy packed by its structure in elementary particle collisions observed by the newest CERN accelerator measurements in which **e** is observed to decay. This subject like the internal structures' border smooth end of the **EM**- field, as well as a few other matters presented here are worth further study beyond the scope of this work.

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Conflicts of interest

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