An Impedance Approach to the Chiral Anomaly

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The chiral potential is inverse square. The family of inverse square potentials includes the vector Lorentz potential of the quantum Hall and Aharonov-Bohm effects, and the centrifugal, Coriolis, and three body potentials. The associated impedances are scale invariant, quantum Hall being the most familiar. Modes associated with scale invariant impedances communicate only quantum phase, not an observable in a single quantum measurement. Modes associated with scale dependent impedances, including among others those of the 1/r monopole and 1/r^3 dipole potentials, communicate both phase and energy. Making this clarifying distinction between phase (relative time) and energy explicit presents a new perspective on the anomaly. This approach is introduced via the Rosetta Stone of modern physics, the hydrogen atom. Precise impedance-based π^0, η, and η' branching ratio calculations are presented as ratios of polynomials in powers of the fine structure constant, followed by discussion. Mass generation via chiral symmetry breaking is not addressed in the present paper.

INTRODUCTION

Anomalies may be defined as "...breakings of classical symmetries by quantum corrections, which arise when the regularizations needed to evaluate small fermion loop Feynman diagrams conflict with a classical symmetry of the theory."[1]

In a finite quantum theory chiral symmetry appears to be broken only by weak interactions. The presence of the anomaly in strong and electromagnetic quantum field theory (QFT) calculations[1–8] seems to be an inevitable result of the regularization needed to remove infinities before mass and charge renormalizations can be accomplished. However, one has a choice - in the presence of the anomaly *either* chiral symmetry *or* gauge invariance must be broken.

The requirement for gauge invariance is driven by the need to maintain phase coherence. In QFT, quantum phase coherence in the presence of potentials is maintained via the covariant derivative. This is essential. A theory without phase coherence is not a quantum theory.

The impedance approach is gauge invariant. Gauge invariance is built in. Complex impedances shift phases. Complex quantum impedances shift quantum phases. The scale invariant impedance associated with the chiral potential[9, 10] communicates quantum phase and only quantum phase[11–13]. No need for the covariant derivative. To understand the flow of energy one need only take the appropriate impedances into account.

The phase-only character of inverse square potentials, their incapacity to do work, is emphasized in the related case of the centrifugal potential of the free Schroedinger particle by Holstein[14]. The symmetry is understood to be scale invariance (unbroken sans regularization).

The impedance approach is finite. Impedance is a geometric concept, depends on size and shape. In the limit of the small, the point/singularity is infinitely mismatched to you and I. We cannot share energy with it. While presumably equally decoupled, the quantum limit of the large is more subtle, in the emergent realm of the classical, and ultimately the cosmological. In both limits, small and large, divergences are removed by the impedance mismatches. Regularization and renormalization are not necessary.

The anomaly does not arise in the impedance approach, a result of the finiteness and gauge invariance.

The chiral current comprises quantum phase and only quantum phase, not a single-measurement observable. With proper inclusion of chiral phase, or more generally appropriate scale invariant impedances, conflict between chiral symmetry and gauge invariance is removed.

What then of the anomaly? QFT relies on the anomaly for calculation of π^0 branching ratios[1–8]. This suggests that an inverse-square potential term is missing from the Lagrangian, that this term would remove the anomaly, and that in its presence the correct π^0 branching ratios would be found sans anomaly.

In what follows the generalization of quantum impedances to all potentials is outlined, and the model upon which the impedance approach is based is presented. Quantum impedance matching is introduced via the Rosetta Stone of modern physics, the hydrogen atom.

The quantum impedance network and the unstable elementary particle spectrum are tied together by the manner in which the coherence lengths of the unstable particles are determined by the α-spaced conjunctions of the scale-dependent mode impedances. This is followed by impedance-based branching ratio calculations of both π^0 and η, and a quantitative discussion of the η'.

The next section (branching ratio calculations) is long relative to the overall length of this note, and focused on details of quantum impedances. The reader less familiar with the concept of impedance might choose to browse to the Discussion, giving good attention to the figures.

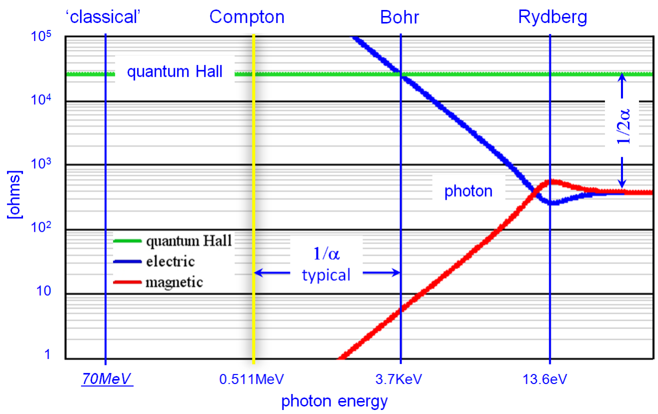

FIG. 1. Far and near field 13.6eV photon and scale invariant electron impedances as a function of spatial scale as defined by photon energy. The role of the fine structure constant α is prominent in the figure.

BRANCHING RATIO CALCULATIONS

Quantum Impedances

Every circuit designer knows - impedances govern the flow of energy. This is not a theoretical musing. Classical or quantum impedances, mechanical or electromagnetic, fermionic or bosonic, topological,... To understand the flow of energy it is essential to understand the relations between the relevant impedances.

A novel method for calculating mechanical impedances[15], both classical and quantum, was presented earlier[12]. In that work a background independent version of Mach's principle emerged from a rigorous analysis of the two body problem, permitting simple and direct calculation of these impedances.

The two body problem is innately one-dimensional. The mechanical impedances derived from Mach's principle can be converted to the more familiar electrical impedances by adding the attribute of line charge density, that of the electric charge quantum confined to the Compton wavelength of the particle in question.

This method of generalizing quantum impedances from the photon and quantum Hall impedances to those associated with all potentials and forces provides a versatile tool, one that has been effectively applied to the elementary particle spectrum, the mechanics of local and nonlocal quantum state reduction, establishment of an exact relationship between gravity and electromagnetism, and a possible resolution of the black hole information paradox[12].

More recently, quantum impedances have been employed in exploring the role of time symmetry in quantum mechanics[13, 16], and the relationship of the impedance approach to other interpretations of the formalism of quantum mechanics has been clarified[11].

The Impedance Model

Physics without calculations is not physics, but rather philosophy. This novel tool, this background independent method of calculating impedances, is of no use to physics without a model to which it may be applied. The model adopted earlier [12] remains useful. It comprises

- quantization of electric and magnetic flux, charge, and dipole moment
- three topologies - flux quantum (no singularity), monopole (one singularity), and dipole (two)
- confinement to a fundamental length, taken to be the Compton wavelength of the electron
- the photon

Coupling impedances of the interactions between these three topologies have been calculated[12, 17], and will be presented later in this note. With the exception of the impedances associated with inverse square potentials, they are parametric impedances, in the sense that they are scale dependent, and consequently energy dependent. As such, one might conjecture that the mismatches provide a confinement mechanism for the mode structures that are present in the impedance model.

The Hydrogen Atom

The aim here is to see what insight may be gained by exploring the role of quantum impedances in the transfer of energy from a 13.6 eV photon to an electron.

In figure 1 the scale invariant far field photon impedance is the red line entering the plot from the right at Z_0 ~377 ohms. The photon impedance is strictly electromagnetic. Unlike massive particles, it has no mechanical impedance. Also shown in the figure is the scale invariant quantum Hall impedance, at R_H ~25.8 Kohm. It is an electromechanical impedance.

The wavelength of the 13.6 eV photon is the inverse Rydberg. The electric and magnetic flux quanta that comprise a photon of that energy decouple there, at the transition from the scale invariant far field to the scale dependent near field[18]. The decoupled flux quanta are not scale invariant, electric going to high impedance and magnetic to low as one moves to shorter length scales.

The far field photon is mismatched to the electron quantum Hall impedance. The electric component of the photon near field dipole impedance (blue) does indeed match the quantum Hall impedance (green) at the Bohr radius. However, for energy to flow smoothly and continuously from the photon to the electron, from the Rydberg to the Bohr radius, requires a smooth and continuous match to an electron dipole impedance, a quantum dipole impedance.

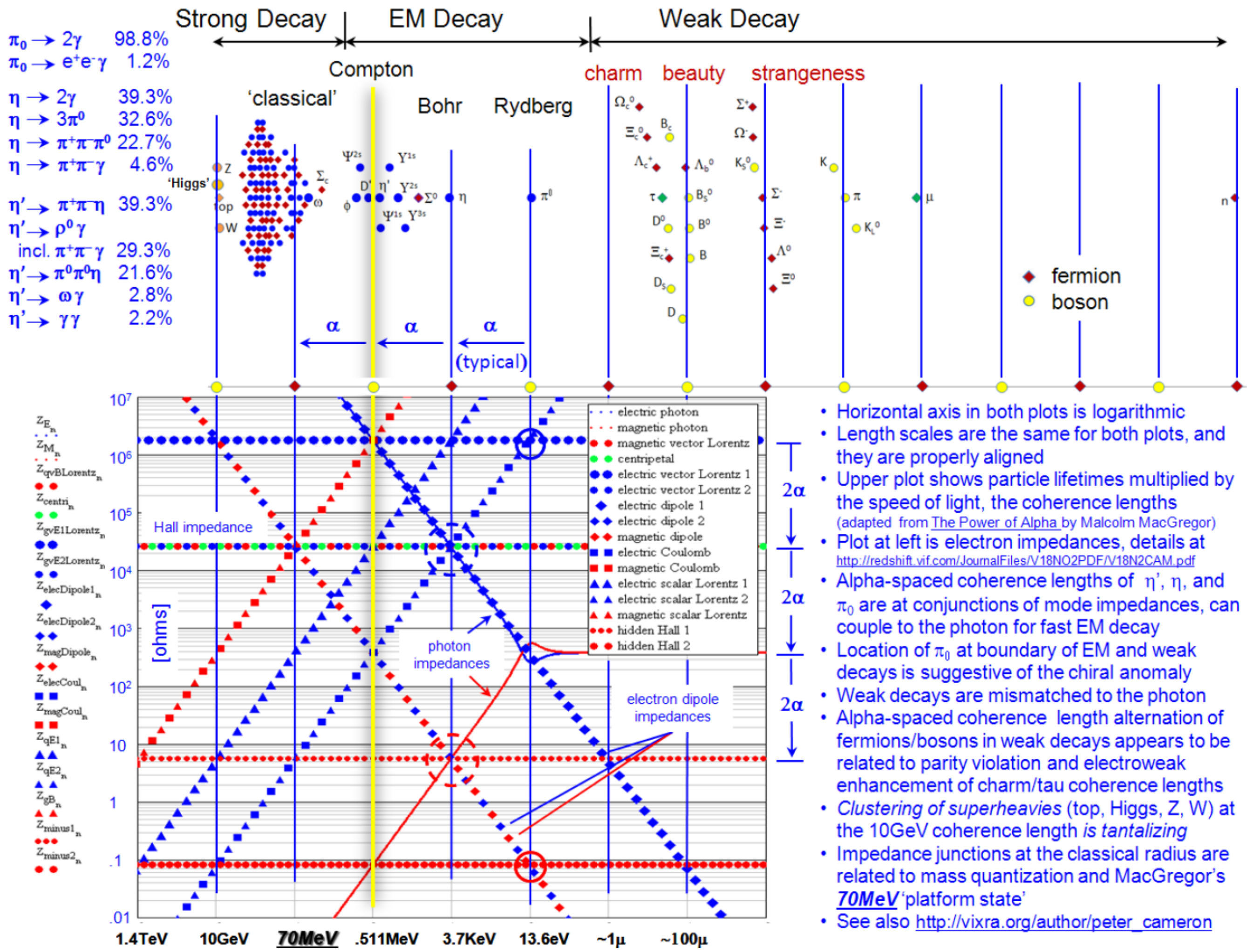

FIG. 2. A composite of 13.6eV photon impedances and a variety of background independent electron impedances[17], measured branching ratios of the π^0, η, and η', the four fundamental quantum lengths shown in fig.1, and the coherence lengths of the unstable particles.[19–21]

While such an impedance is not to be found in the canonical literature, it exists in the impedance model, and is shown in the impedance plot of figure 2. The electric flux quantum is well matched to the larger of the two electric dipole impedances of the electron, the 'external' dipole impedance, where the electric dipole impedances are represented by large and small blue diamonds.

The impedance plot of figure 2 was generated with the electron in mind, with no thought of the hydrogen atom or the photon. It was only later that the photon was added. The resulting smooth impedance match from the photon at the Rydberg to the electron at the Bohr radius and the consequent 'Bohr correspondence' was a nice serendipitous surprise.

As the head of the **electric flux quantum** wavepacket arrives at the Bohr radius the (presumed Gaussian) packet is still feeding increasing energy in from out beyond the Rydberg. From figure 2 it can be seen that at the Bohr radius there is a conjunction (upper dashed circle) of the electron dipole impedance with the scale invariant electric and magnetic vector Lorentz impedances, the scale invariant centrifugal impedance, and the scale dependent electric Coulomb and scalar Lorentz impedances. The details of the couplings between the modes associated with the impedances (phases, confinement mechanisms,...) remain to be investigated. At the outset it is tempting to say that one knows the outcome (the H atom is ionized) and can work backwards from there.

But where is the proton in this plot? Given that the many many short-lived resonances between the 70 MeV classical radius and the 9.59 GeV coherence line are adequately represented by the subset shown (more on the neutrino later), only the proton is absent. What is it that the electron is ionized from by that 13.6 eV photon? The plot is in the rest frame of the electron.

The **magnetic flux quantum** arrives at the Bohr radius without benefit of an impedance match from the scale of the Rydberg, but presumably still phase-coherent. The excitation of the Bohr magneton (an 'internal impedance' denoted by the small red diamonds) at the Bohr radius is presumably proportionally diminished.

The possible existence of a scale invariant five ohm magnetic impedance should be noted. Detailed calculations suggest that the measured quantum Hall impedance is the sum of electric *and* magnetic impedances.

It was shown earlier[12] that all massive particles have an inertial impedance, a centrifugal impedance, represented by the green dots in figure 2. Similar to the case of the five ohm scale invariant magnetic impedance, one might consider the existence of the corresponding additional scale invariant five ohm centrifugal impedance, and perhaps the full family of invariant impedances associated with the inverse square potentials.

The π^0 Branching Ratios

The relatively simple π^0 branching tree is shown in figure 3. As the image suggests, the impedance calculation is done taking the paths in parallel.

As shown in figure 2, the π^0 coherence length coincides with the (inverse) Rydberg, where there is an impedance match via the dipole mode. Ignoring the phases, the impedance of the two photon decay can be written as

$$Z_{\gamma\gamma} = \frac{1}{\frac{1}{Z_0} + \frac{1}{Z_0}} = \frac{Z_0}{2} = 188.37\,\Omega \tag{1}$$

and that of the e$^+$e$^-$$\gamma$ mode as

$$Z_{ee\gamma} = \frac{1}{\frac{1}{R_H} + \frac{1}{R_H} + \frac{4\alpha^2}{Z_0}} = \frac{Z_0}{4\alpha^2 + 4\alpha} = 12\,813\,\Omega \tag{2}$$

where $R_H = \frac{Z_0}{2\alpha}$ is the quantum Hall resistance, so that

$$Z_{\pi 0} = \frac{1}{\frac{1}{Z_{\gamma\gamma}} + \frac{1}{Z_{ee\gamma}}} = \frac{Z_0}{4\alpha^2 + 4\alpha + 2} = 185.64\,\Omega \tag{3}$$

and the branching ratios are

$$\Gamma_{\gamma\gamma} = \frac{Z_{\pi 0}}{Z_{\gamma\gamma}} = \frac{1}{2\alpha^2 + 2\alpha + 1} = 0.9855\,(0.988) \tag{4}$$

$$\Gamma_{ee\gamma} = \frac{Z_{\pi 0}}{Z_{ee\gamma}} = \frac{2\alpha^2 + 2\alpha}{2\alpha^2 + 2\alpha + 1} = 0.0145\,(0.012) \tag{5}$$

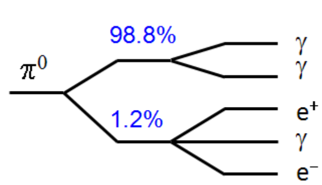

FIG. 3. The π^0 branching tree

Codata 2010 values are shown in parentheses. That the branching ratios can be expressed simply in powers of the fine structure constant is a consequence of the α-spaced conjunctions of the mode impedances. The calculated branching ratios differ from the experimental data by the factor $\sim\alpha/2\pi$, suggesting that a higher-order calculation would be more precise.

The η Branching Ratios

The more complex η branching tree is shown in figure 4. Here we follow the same method as in the previous example, working from top to bottom and right to left in the figure as we calculate. Again ignoring the phases, as well as factors of two that will be addressed in the discussion that follows, the impedance of the two photon decay can be written as

$$Z_{\gamma\gamma} = \frac{1}{\frac{2}{Z_0} + \frac{2}{Z_0}} = \frac{Z_0}{4} \tag{6}$$

The π^0 impedance calculated in the previous section is

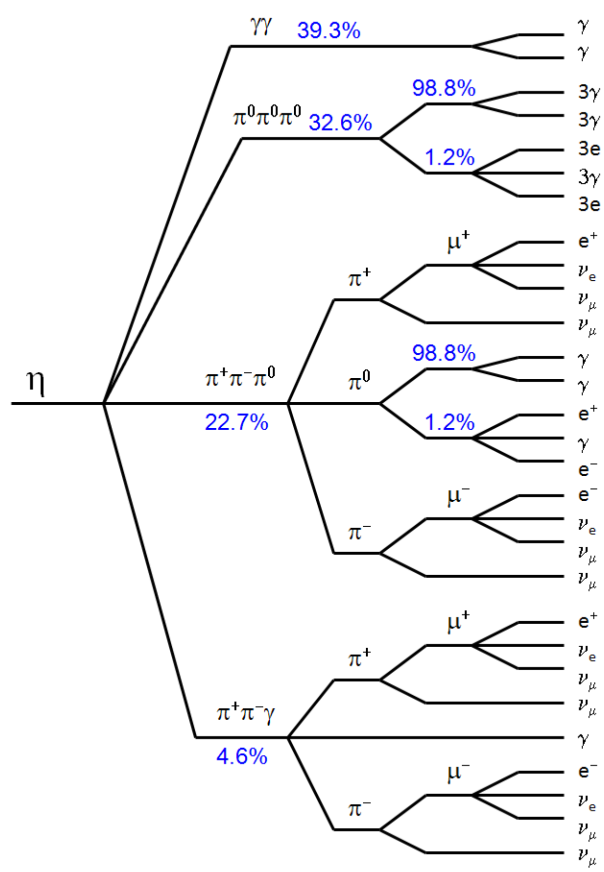

FIG. 4. The η branching tree

used to find that of the three π^0 decay

$$Z_{3\pi 0} = \frac{2}{\frac{1}{Z_{\pi 0}} + \frac{1}{Z_{\pi 0}} + \frac{1}{Z_{\pi 0}}} = \frac{2Z_0}{3(4\alpha^2 + 4\alpha + 2)} \quad (7)$$

We assume the neutrino has rest mass, and therefore a scale invariant centrifugal impedance

$$Z_\nu = R_H = \frac{Z_0}{2\alpha} \quad (8)$$

so that the muon impedance is

$$Z_\mu = \frac{1}{\frac{1}{Z_e} + \frac{1}{Z_\nu} + \frac{1}{Z_\nu}} = \frac{R_H}{3} = \frac{Z_0}{6\alpha} \quad (9)$$

The impedances of the charged pions are then

$$Z_{\pi +} = Z_{\pi -} = \frac{1}{\frac{1}{Z_\nu} + \frac{1}{Z_\mu}} = \frac{Z_0}{8\alpha} \quad (10)$$

and the impedance of the $\pi^+\pi^-\pi^0$ decay is

$$Z_{\pi\pi\pi 0} = \frac{1}{\frac{1}{Z_{\pi +}} + \frac{1}{Z_{\pi -}} + \frac{1}{Z_{\pi 0}}} = \frac{Z_0}{4\alpha^2 + 20\alpha + 2} \quad (11)$$

Finally, the impedance of the $\pi^+\pi^-\gamma$ decay is

$$Z_{\pi\pi\gamma} = \frac{2}{\frac{1}{Z_{\pi +}} + \frac{1}{Z_{\pi -}} + \frac{1}{Z_0}} = \frac{2Z_0}{16\alpha + 1} \quad (12)$$

so that the impedance of the η is

$$\begin{aligned} Z_\eta &= \frac{1}{\frac{1}{Z_{\gamma\gamma}} + \frac{1}{Z_{3\pi 0}} + \frac{1}{Z_{\pi\pi\pi 0}} + \frac{1}{Z_{\pi\pi\gamma}}} \\ &= \frac{2Z_0}{20\alpha^2 + 68\alpha + 19} \end{aligned} \quad (13)$$

and the branching ratios are

$$\begin{aligned} \Gamma_{\gamma\gamma} &= \frac{Z_\eta}{Z_{\gamma\gamma}} = \frac{8}{20\alpha^2 + 68\alpha + 19} \\ &= 0.410\,(0.393) \end{aligned} \quad (14)$$

$$\begin{aligned} \Gamma_{3\pi 0} &= \frac{Z_\eta}{Z_{3\pi 0}} = \frac{3(4\alpha^2 + 4\alpha + 2)}{20\alpha^2 + 68\alpha + 19} \\ &= 0.312\,(0.326) \end{aligned} \quad (15)$$

$$\begin{aligned} \Gamma_{\pi\pi\pi 0} &= \frac{Z_\eta}{Z_{\pi\pi\pi 0}} = \frac{2(4\alpha^2 + 20\alpha + 2)}{20\alpha^2 + 68\alpha + 19} \\ &= 0.220\,(0.227) \end{aligned} \quad (16)$$

$$\begin{aligned} \Gamma_{\pi\pi\gamma} &= \frac{Z_\eta}{Z_{\pi\pi\gamma}} = \frac{16\alpha + 1}{20\alpha^2 + 68\alpha + 19} \\ &= 0.057\,(0.046) \end{aligned} \quad (17)$$

Again, codata 2010 values are shown in parentheses. All four calculated branching ratios are in agreement with the experimental values at better than two parts per hundred. This is also true for the corresponding η' decays of figure 5, as discussed in the next subsection.

The η' Branching Ratios

A simplified η' branching tree is shown in figure 5. Following the same method as in the previous examples gives reasonable results for some of the branches, but not for all. Looking at figure 2, it's easy to see why.

The π^0 coherence length sits at the inverse Rydberg, well isolated from perturbation due to either the η at smaller length scales or τ and the charm family at greater scales. Similarly, the η stands on its own at the Bohr radius, with the Σ^0 nearest neighbor.

Unlike the π^0 and η, the η' is in the thick of it, its coherence length at the Compton wavelength of the electron, in the middle of the mode structure of the excited flavor states. It seems probable that coupling to those states (and perhaps other effects resulting from taking the Compton wavelength to define a fundamental length in the impedance model) will require a more sophisticated treatment than that given here for the π^0 and η.

Again looking at figure 2, it remains that the similarity of the impedance structures at the Bohr radius and the Compton wavelength likely accounts for the similarity in the experimental branching ratio values of the η (shown in parentheses in eqns. 14-17) and the η' (shown in figure 5). The calculated branching ratios for the η (shown in eqns. 14-17) are in agreement with experimental values of both η and η' at better than two parts per hundred. This suggests that, while the constituents of the decays are different, at least in the present case the branching ratios are determined more by the relative impedances of the modes than the identity of the actual topological objects (flux quantum, monopole, dipole,...).

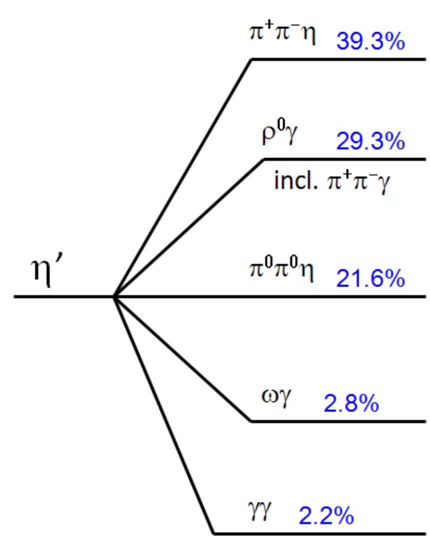

FIG. 5. A simplified η' branching tree

Factors of Two

Unexplained factors of two are present in the impedance model. The first, and most bothersome, appears when the quantum Hall impedance is written in terms of the photon impedance.

$$R_H = \frac{Z_0}{2\alpha} \tag{18}$$

That factor of two is present in the vertical scale of figures 1 and 2, but absent from the horizontal scale. The horizontal axis was rescaled to remove the factors of two. If one looks at the mathcad file that generates the figures[17], the unexplained factor of two becomes apparent. While the Compton radius is where it belongs (it defines the quantization scale), according to the calculations the impedance conjunctions associated with the 'classical' radius should be not at 70MeV

$$r_{classical} = \alpha\lambda_{Compton} \tag{19}$$

but rather a factor of two closer, at 35MeV.

$$r_{junction} = \frac{\alpha}{2}\lambda_{Compton} \tag{20}$$

Similarly, conjunctions at the Bohr radius are a factor of two closer to the Compton wavelength, the Rydberg a factor of four,... The origin and meaning of these factors in the present context is not understood.

Additional factors of two and three offsets are present in the scale dependent impedances, and in the corresponding work of MacGregor[21]. As mentioned earlier[12], without understanding how to properly attribute them (after all, the impedance model is yet in its infancy) and in the interest of simplicity, they were kept in mind but eliminated from the model until such time as they were in need of attention. They could be of help in untangling the mode structures and couplings, understanding what connections might exist with the standard model constituents, sorting out confinement, the phases,...

The phases are as yet undetermined in the impedance plot of figure 2. To calculate branching ratios with the precision shown here requires knowledge of both amplitude and phase. Fortunately, the phase information is given by the experimental data, by the measured coherence lengths of the unstable particles. This data is utilized via the coherence length correlation with the α-spaced conjunctions of the mode impedances.

Without phases to help tie the modes together, there are as yet no dynamics in the impedance plot. Dynamics requires change. Quantum dynamics requires *phase-coherent* change of quantum phase, which requires knowledge of mode structures and couplings. Given sufficient computational resources, such knowledge seems accessible via iterative tuning of the impedance network phases and mode structures to fit the data. Matlab seems like an obvious choice, running on a gate array farm.

DISCUSSION

Historical Perspective on Quantum Impedances

Impedances govern the flow of energy. This is a fundamental concept of universal applicability. Historically, it has been overlooked in quantum theory.

The 1980 discovery[22] of a new fundamental constant of nature, the Nobel Prize discovery of exact impedance quantization in the quantum Hall effect, was greatly facilitated by scale invariance. This classically peculiar impedance is topological, the measured resistance being independent of the size or shape of the Hall bar. Prior to that discovery, impedance quantization was more implied than explicit in the literature[23–28].

In the 1959 thesis of Bjorken[25] is an approach summarized[29] as "...an analogy between Feynman diagrams and electrical circuits, with Feynman parameters playing the role of resistance, external momenta as current sources, and coordinate differences as voltage drops. Some of that found its way into section 18.4 of..." the canonical text[26]. As presented there, the units of the Feynman parameter are [sec/kg], the units of *mechanical conductance*[15]. Form factors are proportional to conductances, inversely proportional to resistances.

With the confusion that resulted from interpreting conductance as resistance, and more importantly lacking the concept of quantized impedance, the anticipated intuitive advantage of the circuit analogy[26] was lost and the possibility of the jump from well-considered analogy to a photon-electron impedance model was not realized.

Like the first Rochester Conference on Coherence and Quantum Optics in 1960, the 1963 paper/thesis by Vernon and Feynman[27] on the "Interaction of Systems" was motivated by the invention of the maser. It is a particularly suggestive combination of the languages of the electrical engineer and the physicist. The authors devoted a thesis to the concepts needed for impedance matching to the maser. However, lacking again was the explicit concept of quantized impedance in the maser.

Had exact impedance quantization been discovered in 1950 rather than 1980, one wonders whether the impedance concept might have found its way into the foundation of QED at that time, before it was set in the bedrock, to underpin rather than illuminate electroweak theory, QCD, and gravity[12, 30–39].

Since the pivotal 1980 discovery, and particularly in the past few years, understanding of quantum impedance in electron dynamics, and particularly condensed matter, has been expanding at an accelerating rate, as shown by a sampling of the literature [40–85].

Extending the understanding beyond the photon and Landauer/quantum Hall impedances to the generalized impedances associated with all potentials appears to offer great promise in condensed matter physics[86]. Un-

	'spinor' flux quantum	monopole charge quantum	dipole dipole quantum
electric	dark	observable	dark
magnetic	observable	dark	observable

FIG. 6. Alternation of dark and observable with topology

like the particle physics focus of the present approach, the relevant length scale for the appropriate electron impedance network in condensed matter is not the Compton wavelength but rather the deBroglie wavelength, the wavelength associated with the Doppler-shifted Compton frequency[87].

'Dark' Modes and Anomalies

The impedance plot of figure 2 is not complete.

Absent are the longitudinal dipole-dipole impedances, the longitudinal and transverse charge-dipole impedances (the charge-dipole impedances are a subset of the scale invariant three body impedances), and the Coriolis impedance. There may be others, and likely are. Given the spin dependence of the weak interaction, one would expect that adding the longitudinal impedances to the figure would give additional insight into the weak decays, probably essential for instance in impedance-based calculations of those branching ratios.

Present in the plot are several impedances that (excepting the unstable particle spectrum) are absent in our observations of the world, do not couple to the photon, namely those associated with the electric flux quantum, magnetic monopole, and electric dipole. Figure 6 shows the alternation with topological complexity.

We see the magnetic flux quantum, electric monopole, and magnetic dipole in the stable particles which comprise our physical world, but not their electromagnetic complements. It seems that the only place we see these 'dark' components is in the unstable particle spectrum. This broken symmetry is partially understood in terms of the relative strengths of the magnetic and electric charge quanta[12, 88], and might have a not-yet-obvious role in the chiral anomaly.

Gravitational Anomalies

The impedance approach gives a fresh perspective on anomalies in quantum theory. The chiral anomaly exists in theories of gravity as well. In that case it would seem that there are at least three scale invariant impedances that must be considered (three body, centrifugal, and Coriolis) and three scale dependent impedances (monopole, dipole, and quadrupole), as well as a possible role for a 'gravitational flux quantum'.

The question here is whether an impedance approach to gravitation would be anomaly free. And perhaps whether an understanding of the phases associated with the mass-related impedances might inform gauge theories of quantum gravity[89–91].

CONCLUSION

Impedances govern the flow of energy. This is a fundamental concept of universal applicability. Historically, it has been overlooked in quantum theory.

The impedances associated with inverse square potentials are scale invariant. Scale invariant impedances cannot couple energy - they only communicate phase. To the extent that chirality can be identified with spin[92], this suggests that a causative mechanism in quantized spin is quantum phase.

For the photon this is obvious. The far field impedance is scale invariant, and the angular momentum is defined by the relative phase of the constituent electric and magnetic flux quanta. Witness the quarter wave plate.

For fermions, and massive particles in general, identifying the constituent fields is not so straightforward. The first and most serious obstacle is assumption of perfectly impedance matched point particles in quantum field theory. The second is perhaps abstraction of the fields in the creation and annihilation operators. These obstacles are absent in the impedance approach.

The impedance approach suggests that spin is at least partially a manifestation of the phases communicated by the relevant impedances. In the impedance approach these phases are associated with identifiable modes. One wonders what a quarter wave plate for the proton looks like. And what changes when one goes from longitudinal to transverse, where spin effects are prominent[93].

Despite the remarkable elegance and power of the standard model, proton spin structure remains a mystery[93–96]. The hope is that this preliminary impedance approach to phenomena associated with the chiral anomaly will motivate and illuminate the role of anomalies in proton spin, and a deeper understanding of spin itself.

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