Impedance Quantization in Gauge Theory Gravity

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Geometric algebra is universal, encompassing all the tools of the mathematical physics toolbox, is background independent, and is the foundation of gauge theory gravity. Similarly, impedance is a fundamental concept of universal validity, is background independent, and the phase shifts generated by impedances are at the foundation of gauge theory. Impedance may be defined as a measure of the amplitude and phase of opposition to the flow of energy. Generalizing quantum impedances from photon and quantum Hall to all forces and potentials generates a network of both scale dependent and scale invariant impedances. This essay conjectures that these quantized impedances can be identified with the gauge fields of gauge theory gravity, scale dependent with the translation field and scale invariant with rotation.

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INTRODUCTION

This essay incorporates two specialties unfamiliar to many readers. The more prominent is the geometric (Clifford) algebra approach to gauge theories of gravity[1–3], the more arcane generalization of quantized impedances beyond the photon far-field and electron quantum Hall impedances to those associated with all forces and potentials[4, 5]. A substantial portion of this essay is devoted to summarizing essential features of these specialties and exploring their absence from the core of mainstream physics. Focus then shifts to the conjectured role of impedance quantization in gauge theory gravity.

GEOMETRIC ALGEBRA AND GAUGE THEORY GRAVITY

Figure 1 shows the evolution of geometric algebra[6], illustrating an important point - geometric algebra encompasses essentially all the mathematical tools of the physicist[7–9], can be considered a 'grand unified theory' of mathematical physics.

Hermann Grassman was "...a pivotal figure in the historical development of a universal geometric calculus for mathematics and physics... He formulated most of the basic ideas and... anticipated later developments. His influence is far more potent and pervasive than generally recognized."[10] Among many accomplishments, he introduced[11, 12] the bivector outer (or wedge) product $a \wedge b$ shown in figure 2.

Grassman's work lay fallow until Clifford[13] "...united the inner and outer products into a single *geometric* product. This is associative, like Grassman's product, but has the crucial extra feature of being *invertible*, like Hamilton's quaternion algebra."[14] While Clifford algebra attracted considerable interest at the time, it was "...largely abandoned with the introduction of what people saw as a more straightforward and generally applicable algebra, the *vector algebra* of Gibbs." [8]

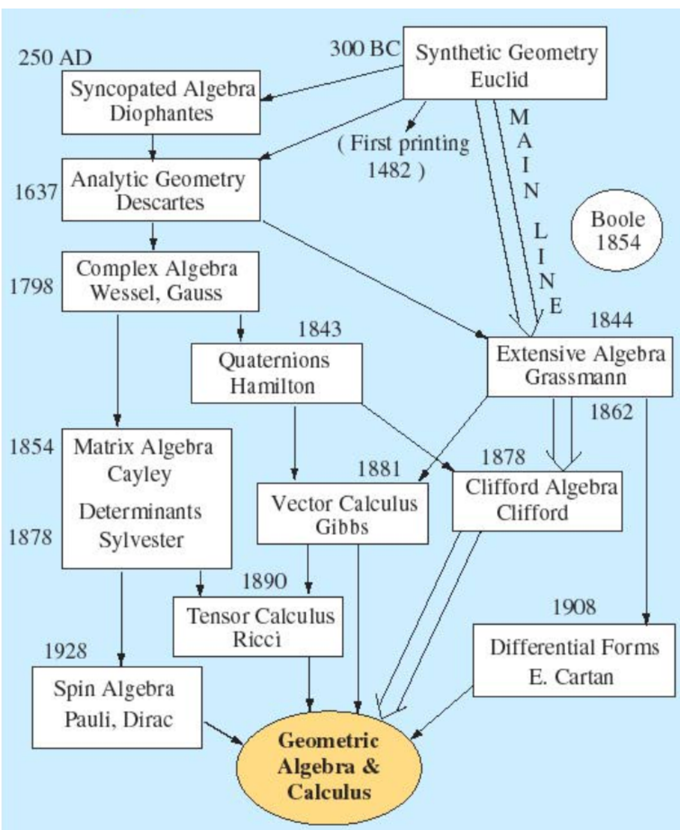

FIG. 1: Evolution of Geometric Algebra[6]

The geometric product ab mixes products of different dimension, or *grade*. In two dimensions $ab = a \cdot b + a \wedge b$, the inner product $a \cdot b$ being grade 0 and the outer product grade 2. Mixing of grades makes geometric algebra unique in the ability to handle geometric concepts in any dimension.

With the death of Clifford at age 33 in 1879, the absence of an advocate for geometric algebra to balance the powerful Gibbs contributed to the neglect of geometric algebra. "This was effectively the end of the search for a unifying mathematical language and the beginning of a proliferation of novel algebraic systems..."[8]

Geometric algebra resurfaced, unrecognized as such, as algebra without geometric meaning in the Pauli and Dirac matrices, then with a few isolated exceptions (again without geometric meaning) remained dormant until taken up by David Hestenes almost four decades later[15].

The significance of Hestenes' ongoing elaboration and promotion of geometric algebra is not easily overemphasized, as can be seen by a visit to the website of the upcoming Barcelona conference on geometric algebra[16]. Of interest here is the application of spacetime algebra to gauge theory gravity, particularly the use of translational and rotational gauge fields in formulating the theory, and in the demonstrated equivalence of gauge theory gravity in flat space with general relativity in curved space[1, 2, 8]. The role of impedance quantization in adding both logical clarity and intuitive appeal to the theory will become clear in what follows.

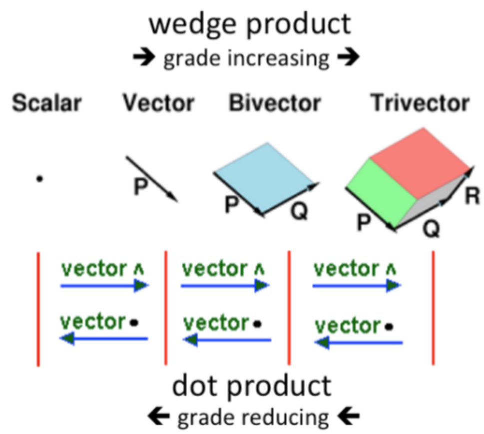

FIG. 2: Geometric algebra components in three dimensions. The two products (dot and wedge or inner and outer) that comprise the geometric product raise and lower the grade[17]

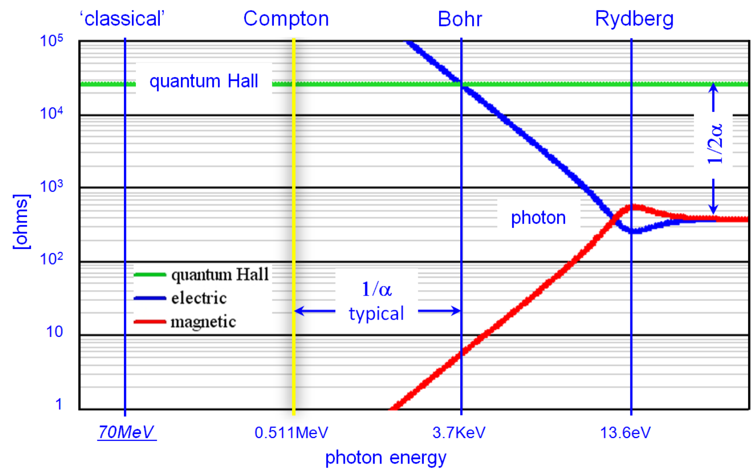

FIG. 3: Four fundamental lengths, far and near field 13.6eV photon impedances[20], and scale invariant electron quantum Hall impedance as a function of spatial scale as defined by photon wavelength/energy. The fine structure constant α is prominent in the figure.

GENERALIZATION OF QUANTUM IMPEDANCES

Like the absence of geometric algebra from mainstream mathematical physics, the absence of quantized impedances from gauge theory is an historical accident[18], a consequence of the order in which experimentalists revealed essential relevant data. The foundation of QED was set three decades before the 1980 discovery of exact impedance quantization[19]. Its significance can be seen by examining energy flow between a 13.6 eV photon[20] and the quantum Hall impedance of the electron. Figure 3 illustrates the scale-dependent impedance match that permits energy to flow without reflection between Rydberg and Bohr, between photon and hydrogen atom.

The force operative in the quantum Hall effect is the vector Lorentz force. Impedance quantization is a possibility for all forces[5]. Quantizing with electromagnetic forces only and taking the quantization length to be the electron Compton wavelength gives the impedance network of figure 4. The nodes are strongly correlated with the unstable particle coherence lengths[21, 22], suggesting that, as in the hydrogen atom, energy flows to and from the particle spectrum via this network of electron impedances.

Given a quantization length, what does one quantize? With electromagnetic fields only, taking maximal symmetry between electric and magnetic, and taking the simplest topologies needed for a realistic model gives

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

Figure 4 shows calculated coupling impedances of interactions between these topologies[5, 23]. Defining a quantization length has consequences:

- Low and high energy impedance mismatches of scale dependent modes, here centered on the electron Compton wavelength, provide natural cutoffs. The impedance approach is finite.
- Mismatches as one moves away from the quantization length provide a natural confinement mechanism.

The impedance approach is not only naturally finite and confined, but also naturally gauge invariant. Classical complex impedances - inductance and capacitance - shift phase. Complex quantum impedances shift quantum phase. In gauge theories the phase coherence that distinguishes quantum systems from classical is maintained by the artifice of the covariant derivative. In the impedance approach one need only account for phase shifts introduced by the impedances.

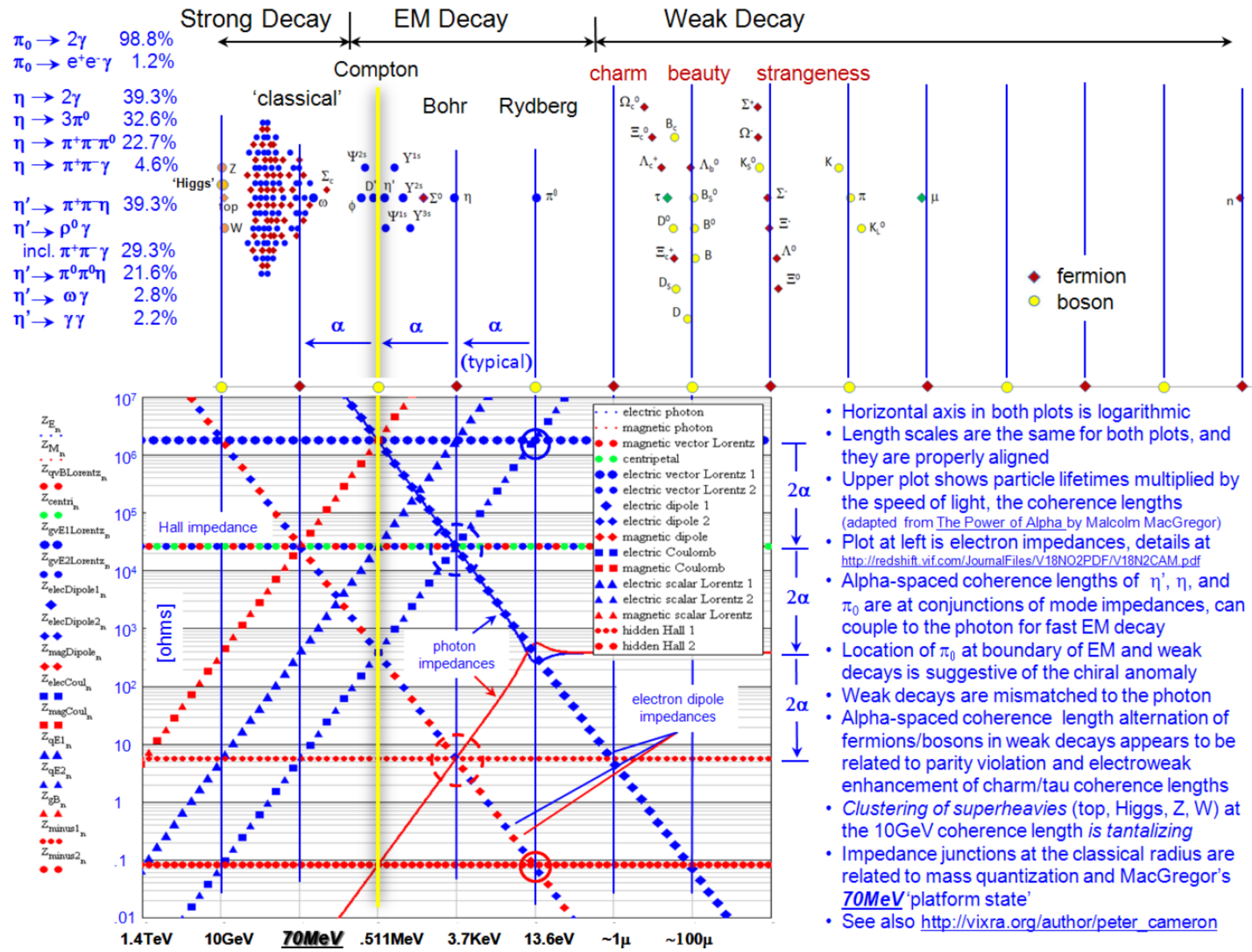

FIG. 4: A composite of 13.6eV photon impedances and a variety of electron impedances[23], measured branching ratios of the π^0, η, and η' [24], four fundamental quantum lengths shown in figure 3, and coherence lengths of the unstable particles.[25–27]

THE PLANCK PARTICLE

Just as the energy of a photon whose wavelength is the electron Compton wavelength equals the electron rest mass, the energy of a photon whose wavelength is the Planck particle Compton wavelength is the rest mass of the Planck particle and its associated event horizon. This is the 'electromagnetic black hole', the simplest Planck particle eigenstate. A more detailed model can be had by taking the quantization length to be not the electron Compton wavelength, but rather the Planck length, resulting in the network of figure 5.

Calculating the impedance mismatch between electron and Planck particle gives an identity between electromagnetism and gravity[28, 29]. The gravitational force between these two particles is equal to the impedance mismatched electromagnetic force they share. The gravitational constant G, by far the most imprecise of the fundamental constants, cancels out in the calculation. This result suggests that both gravity and rest mass are of electromagnetic origin. While strong classical arguments have been advanced against electromagnetic theories of gravity[30], preliminary examination suggests that such arguments fail when the full consequences of quantum phase coherence are taken into consideration.

The impedance approach delivers exact results at the Planck particle event horizon (and beyond to the singularity, completely decoupled by the infinite mismatch to the dimensionless point). Relativistic curvature corrections are unneeded. The impedance model is flat space.

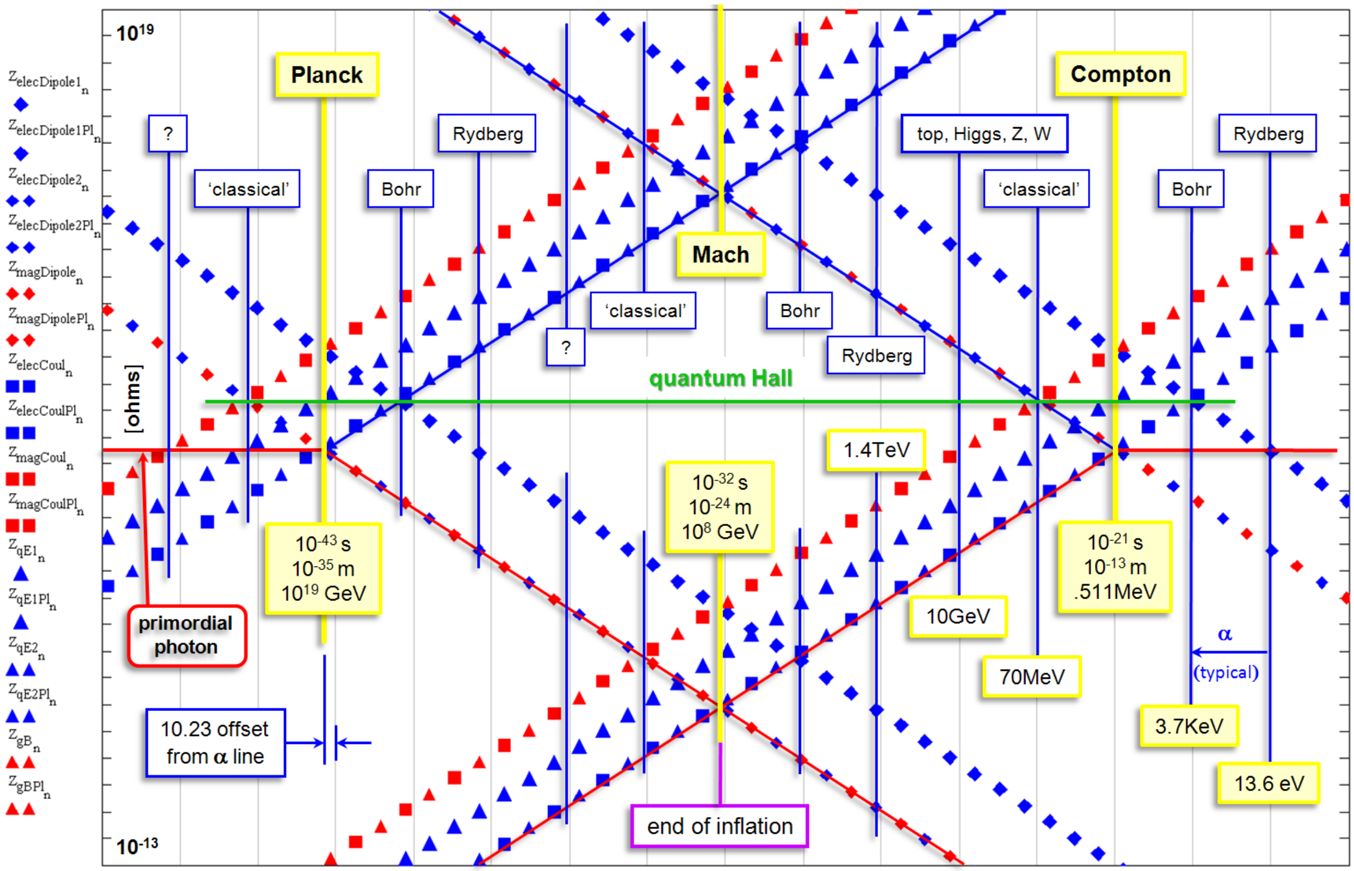

FIG. 5: A subset of the Planck and Compton particle impedance networks, showing a .511 Mev photon entering from the right and the primordial photon from the left[31]. Inflation ends at the intersection of the two impedance networks, referred to here as the 'Mach scale'[29, 32]

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THE CONJECTURE

The connection between the impedance model and geometric algebra goes deep, to the coordinate-free background independence essential for quantum gravity[33]. Clifford Algebra uses a coordinate-free representation. Motion is described with respect to a coordinate frame defined on the object in question rather than to an external coordinate system. Similarly, impedances are calculated from Mach's principle applied to the two body problem[4]. Motion is described with respect to a coordinate frame on one of the bodies. The two body problem is inherently background independent. There is no independent observer to whom rotations can be referenced, only spin.

It is precisely this shared property of geometric algebra and the impedance model, this background independence, that permits the scale invariant impedances (quantum Hall, chiral, centrifugal, Coriolis, three body,...) of the impedance model to be associated with the rotation gauge field of gauge theory gravity, and the scale dependent impedances (all the rest) with the translation gauge field.

The quantum phase coherence of the gauge fields is maintained via their covariant derviatives. Equivalently, the phase shifts generated by the quantum impedances create the probability distributions, the interference effects we measure. The conjecture is that either way it is the same gauge theory, seen from two complementary perspectives, that impedance quantization makes gauge theory gravity a little more real.

CONCLUSION

The possibility that gauge theory gravity and generalized quantum impedances might be linked in such a way as to lead to a viable theory of quantum gravity appears to merit investigation. The author thanks Michaele Suisse for helpful discussions and literature searches, and family and friends for unfailing support and encouragement.

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