Quantum Gravity in the Fano Plane

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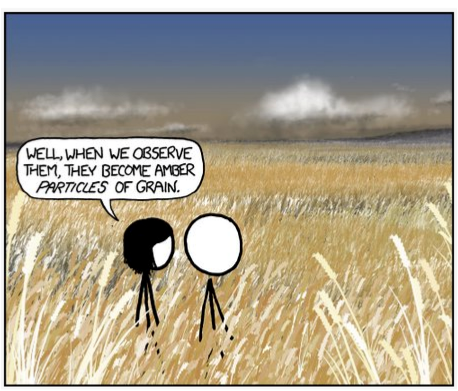
The argument that modern string theory has become **lost in math** is compelling, controversial, and ever more timely[1–4]. A perspective arguably of equal compulsion takes the view that the math is just fine, that string theory has become **lost in physics**. It's all about the wavefunction. Almost a century after Bohr and Copenhagen, ongoing proliferation of conflicting quantum interpretations of the unobservable wavefunction and its interactions attests to the profound confusion in philosophical foundations of basic quantum physics[5–8]. Taking the octonion wavefunction to be comprised not of one-dimensional oscillators in eight-dimensional space, but rather the eight fundamental geometric objects of the Pauli algebra of 3D space - one scalar, three vectors, three bivector pseudovectors, and one trivector pseudoscalar - yields a long overdue and much needed coherent phenomenology.

"Theoretical physics risks becoming a no-mans-land between mathematics, physics and philosophy that does not truly meet the requirements of any."
George Ellis and Joe Silk[9]

"A knowledge of the historic and philosophical background gives that kind of independence from prejudices of his generation from which most scientists are suffering. This independence created by philosophical insight is - in my opinion - the mark of distinction between a mere artisan or specialist and a real seeker after truth."
Albert Einstein[10]

"To understand the electron would be enough."
Albert Einstein[11]



Shared plight of the philosopher
and her mathematician friend,
in search of the physicist's wavefunction....[12]

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INTRODUCTION

Geometric representation of Clifford algebra permits defining vacuum wavefunction components to be the eight fundamental geometric objects of the Pauli algebra of 3D space (fig.1), with wavefunction interactions generating the sixteen component Dirac algebra of flat 4D Minkowski spacetime[13, 14].

Wavefunction physical manifestation follows from introducing the coupling constant $\alpha = \frac{e^2}{2\epsilon_0 hc}$. The four fundamental constants that define α permit assigning topologically appropriate quantized fields to the eight wavefunction components, and to calculate quantized impedance networks of wavefunction interactions[15].
This is important: Impedance matching governs amplitude and phase of energy flow, of information transmission.

Impedance analysis of geometric wavefunction interactions offers insights into quantum gravity effective on all scales, spanning singularity to Planck length to elementary particle Compton wavelengths to deBroglie wavelengths and condensed matter, and finally to the boundary defined by farthest reaches of the observable universe.

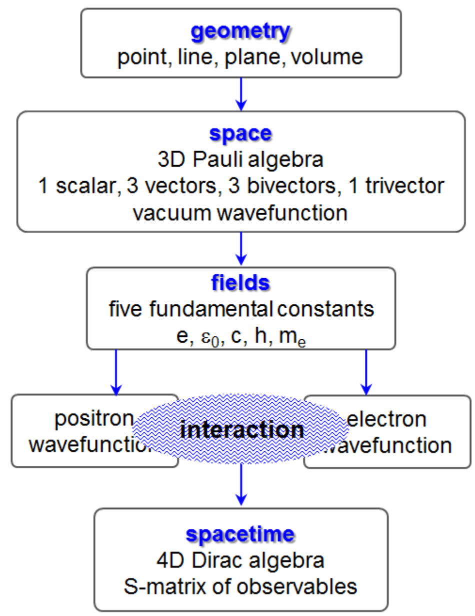

FIG. 1: The Theoretical Minimum

1. GEOMETRIC ALGEBRA

The mathematical language of quantum physics is Clifford algebra. Modern usage employs abstract *matrix representations* of Pauli and Dirac, a historical accident. Intent of Grassman and Clifford was the intuitive spatial algebra of geometric objects, a *geometric representation* [16–19]. Clifford himself called it Geometric Algebra.

Geometric representation was **lost in physics** in the late 1800s, with absence of advocates to balance the powerful Gibbs and Heaviside, whose less comprehensive vector algebra remains prevalent today[20].

"This was effectively the end of the search for a unifying mathematical language and beginning of a proliferation of novel algebraic systems..."[21].

Geometric algebra remained dormant until taken up and extended by David Hestenes[22] in the 1960s. Four decades passed before he was awarded the 2002 Oersted medal for *"Reforming the Mathematical Language of Physics"* by the American Physical Society[23].

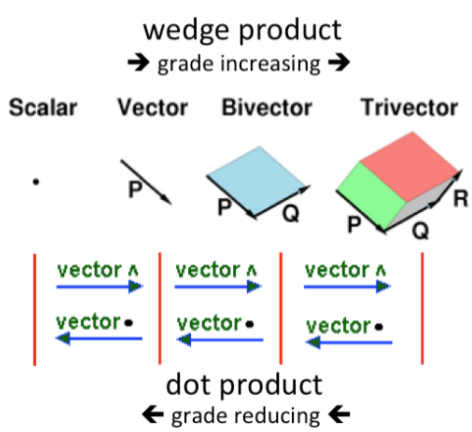

FIG. 2: Geometric algebra components and operations in three dimensions[27].

Casting wavefunctions in geometric representation, what remains is to specify orientations. Scalar is point charge, has the phase degree of freedom - clockwise or counter, matter or antimatter. Vectors and pseudovector bivectors have three orientational DOFs of 3D space. Pseudoscalar trivector is magnetic charge, topological dual of the scalar[24]. These comprise a minimally complete Pauli algebra of space, a geometric representation of the eight-component Pauli vacuum wavefunction. String theory octonion 'dimensions' are orientational DOFs of the vacuum wavefunction. Ambiguity between dimensions and DOFs resolves by denoting spatial dimensionality by 'grade' (fig.2). Scalars are grade 0, vectors grade 1,... [25].

Wavefunction interactions are modeled by geometric products (fig.2). The two products - dot and wedge or inner and outer - comprising the product raise and lower grades. For example, the product of two grade 1 vectors a and b is $ab = a \cdot b + a \wedge b$, the inner product $a \cdot b$ being a grade 0 scalar and outer $a \wedge b$ grade 2 bivector.

Mixing of grades makes geometric algebra unique, topological symmetry breaking[26] yielding 'dynamic supersymmetry'. Bivectors are fermions; scalars, vectors and trivectors are bosons.

2. PHYSICAL MANIFESTATION

Physical manifestation of the vacuum wavefunction requires coupling, assigning topologically appropriate quantized fields to wavefunction components (fig.1). This is accomplished via four fundamental constants that define the electromagnetic coupling constant - electric charge quantum e and permittivity of space ϵ_0, speed of light c, and Planck's angular momentum quantum h (SI units):

$$\alpha = \frac{e^2}{2\epsilon_0 hc} \approx 0.007 \qquad 1/\alpha \approx 137 \tag{1}$$

To set the scale of space requires an additional constant, the electron Compton wavelength ($\lambda_e = h/m_e c$), lightest rest mass particle, the 'mass gap'.

The previous section assigned the octonion's eight 'dimensional' degrees of freedom to the vacuum wavefunction's orientational DOFs, the *geometry layer*. The previous paragraph used α to define topologically appropriate quantized fields, assigning these as well to the octonion, the *fields layer*, bringing the model to the ten 'dimensions' of string theory. Time emerges naturally from interactions, relative phases encoded in 4D pseudoscalars of S-matrix spacetime.

Given that fields of quantum field theory are quantized, it is unavoidable that interaction impedances are likewise quantized. *This is important:* Impedance matching governs amplitude and phase of energy flow, of information transmission. Absence of impedance quantization from QED is most remarkable, to be so **lost in physics**[28].

An essential point distinguishes between scale-dependent and invariant impedances.

Invariant impedances, generalizations of Chern-Simons[29], are topological. Resulting motion is perpendicular to applied force. They cannot do work, transmit information, or be shielded. They include vector Lorentz of quantum Hall and Aharonov-Bohm effects, chiral, centrifugal, Coriolis, and three-body. They're acausal, channels of non-local entanglement, transmit only phase, not a single measurement observable. Associated potentials are inverse square, identified with anomalies in QFT[30].

Scale-dependent impedances are geometric, include Coulomb, scalar Lorentz, dipole-dipole, and photon near field. They are local, causal, transmit both amplitude and phase. Photon appears unique in having both scale-dependent near field and invariant far field impedances. Logarithmic dependence renders impedances parametric[31, 32], non-linearity permitting noiseless frequency domain translation of energy essential to quantum dynamics.

2.1 The Hydrogen atom, Rosetta Stone of Atomic Physics

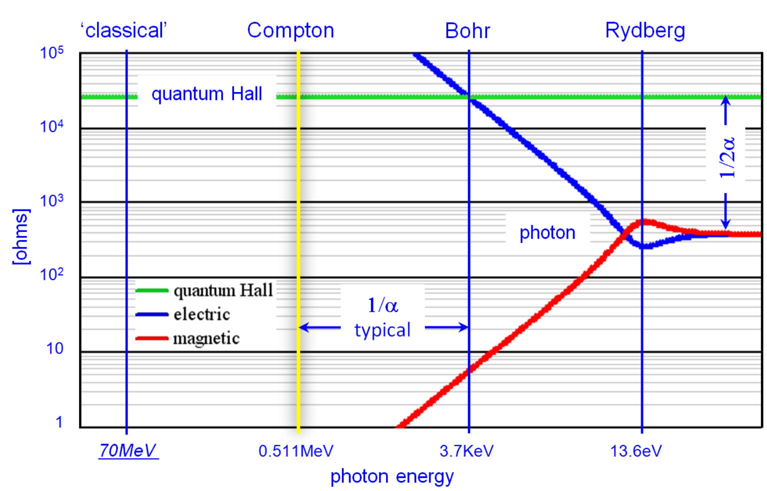

FIG. 3: Photon impedance match to a single free electron[33].

Figure 3 shows four fundamental lengths of the electron and corresponding energies of same wavelength photons, quantum Hall impedance, and impedance of a 13.6 eV photon entering from right. When separated by the inverse Rydberg, near-field electron dipole impedance (blue diamonds in fig.4) shifts relative phase of electric and magnetic flux quanta comprising the photon, decoupling them. Energy flows via dipole impedance to the Bohr radius, coupling via quantum Hall (circles) to capacitive Coulomb (squares) and scalar Lorentz (triangles) modes, oscillating with the inductive dipole impedance.

Here the mainstream community is lost, at the outset of exploring the Rosetta stone. Photon near field impedance[34] is not to be found in textbooks, curricula, or journals of PhD physicists, is absent from our education and practice.

What governs energy transmission in photon-electron interactions, the foundation of QED, is **lost in physics**.

It remains curious that the proton's inertial mass is absent from the electron rest frame of figure 3, that H atom dissociation energy appears to be an 'intrinsic' electron property. And interesting to note there is no impedance match to the photon at the Bohr radius (fig.4), perhaps accounting in part for stability of atoms.

2.2 Unstable Particle Spectrum

Wavefunction interactions generate an impedance representation of the S-matrix[35–37]. Figure 4 shows a portion of the impedance network when excited, and resulting correlation with unstable particle lifetimes, their causal light cone coherence lengths, like network nodes and mode impedances, naturally arranged in powers of α.

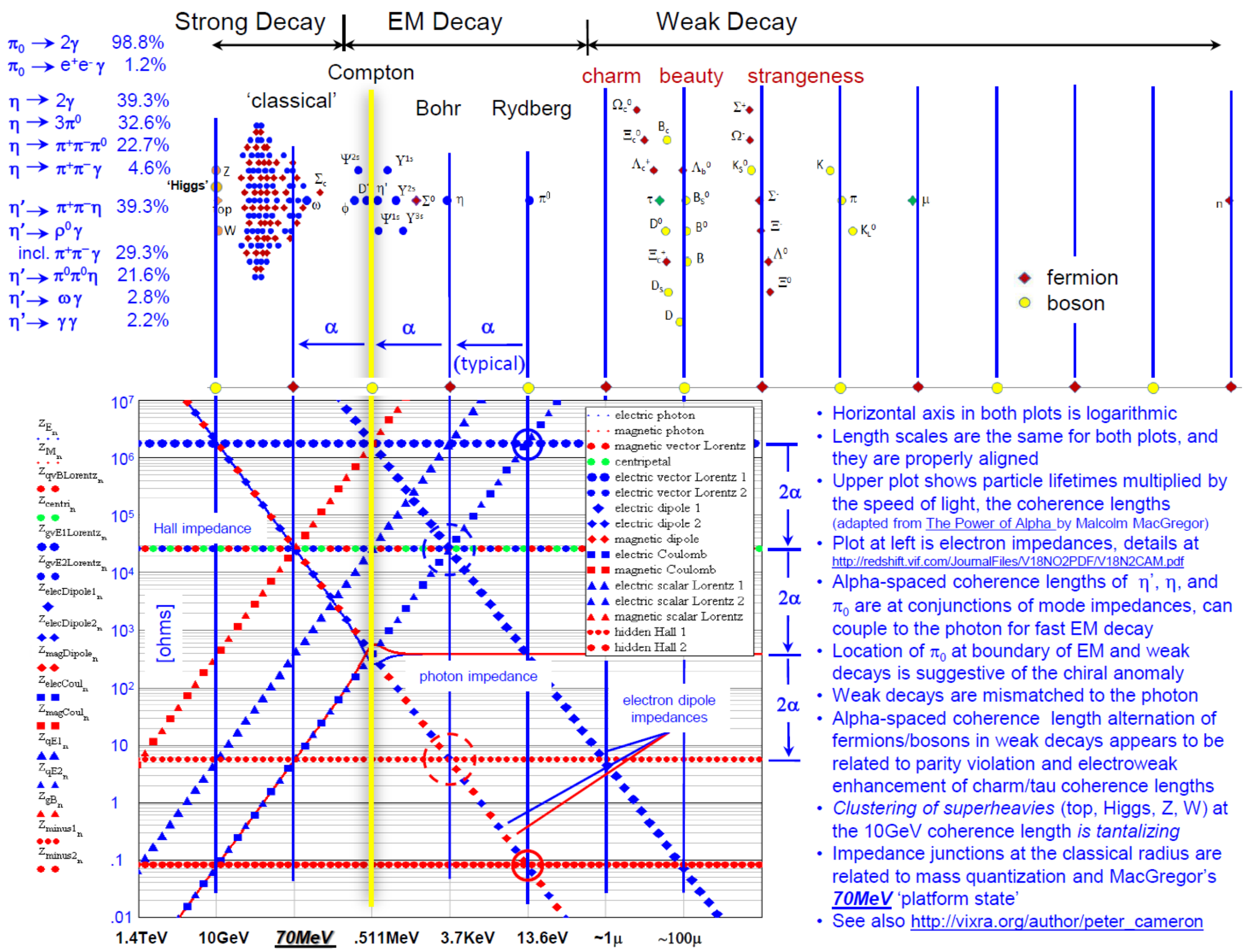

FIG. 4: Correlation of lifetimes/coherence lengths of unstable particle spectrum[38–40] with nodes of network generated by excitation of lightest rest mass manifestation (mass gap) of vacuum wavefunction[41].

Correlation follows from requirement that impedances be matched for energy transmission between modes essential for particle decay, a plausible explanation for unstable particle lifetimes[41].

Gauge invariance follows naturally from the fact that impedance matching governs phase of wavefunction interactions. It's what impedances do - they shift phases.

Confinement follows from mismatch reflections as modes try to propagate away, *exact* matching at nodes being the origin of **asymptotic freedom**. Strong and weak nuclear 'forces' are electromagnetic in origin, confinement arising from impedances of vacuum wavefunctions excited by a given particle[42].

Finiteness is the flip side of confinement. Mismatch to singularity is infinite. Point capacitance is nil, inductance infinite. Singularity is totally decoupled, although mismatch to Planck length plays pivotal role in quantum gravitation.

2.3 Impedance Matching to the Planck Length

Not all are in agreement that Einstein whole-heartedly endorsed curved space interpretations. He expressed this quite clearly in politically correct private communication:

"It is wrong to think that 'geometrization' is something essential. It is only a kind of crutch for finding of numerical laws. Whether one links 'geometrical' intuitions with a theory is a ... private matter."[43]

Riemann's curvature tensor[44] preceded general relativity by six decades. Absent Clifford's geometric interpretation, Einstein's adoption of Riemann's formalism led inevitably to dominance of curved space interpretations.

Equivalence of curved spacetime general relativity with flat 4D Minkowski spacetime gauge theory gravity was introduced by the Cambridge group and Professor Hestenes, and elaborated upon by them over the course of following decades.[45–51]. Impedance quantization offers immediate possibilities for quantizing gravity at the Planck length[52–54]. Impedance mismatches between Compton and Planck wavefunctions reveal an identity. Gravitational force between the two wavefunctions equals mismatch-attenuated electromagnetic force they share, at the part-per-billion accuracy of our five fundamental constants input by hand. Newton's big G cancels out in the ratio of ratios establishing the identity.

Flat spacetime phase shifts of electromagnetic wavefunction interactions are the gauge theory gravity equivalent of spatial curvature of general relativity. While strong classical arguments have been advanced against electromagnetic models of gravitation[55], preliminary examination suggests such arguments fail point-by-point when full consequences of geometric wavefunction interaction impedances enter gauge theory gravity[56].

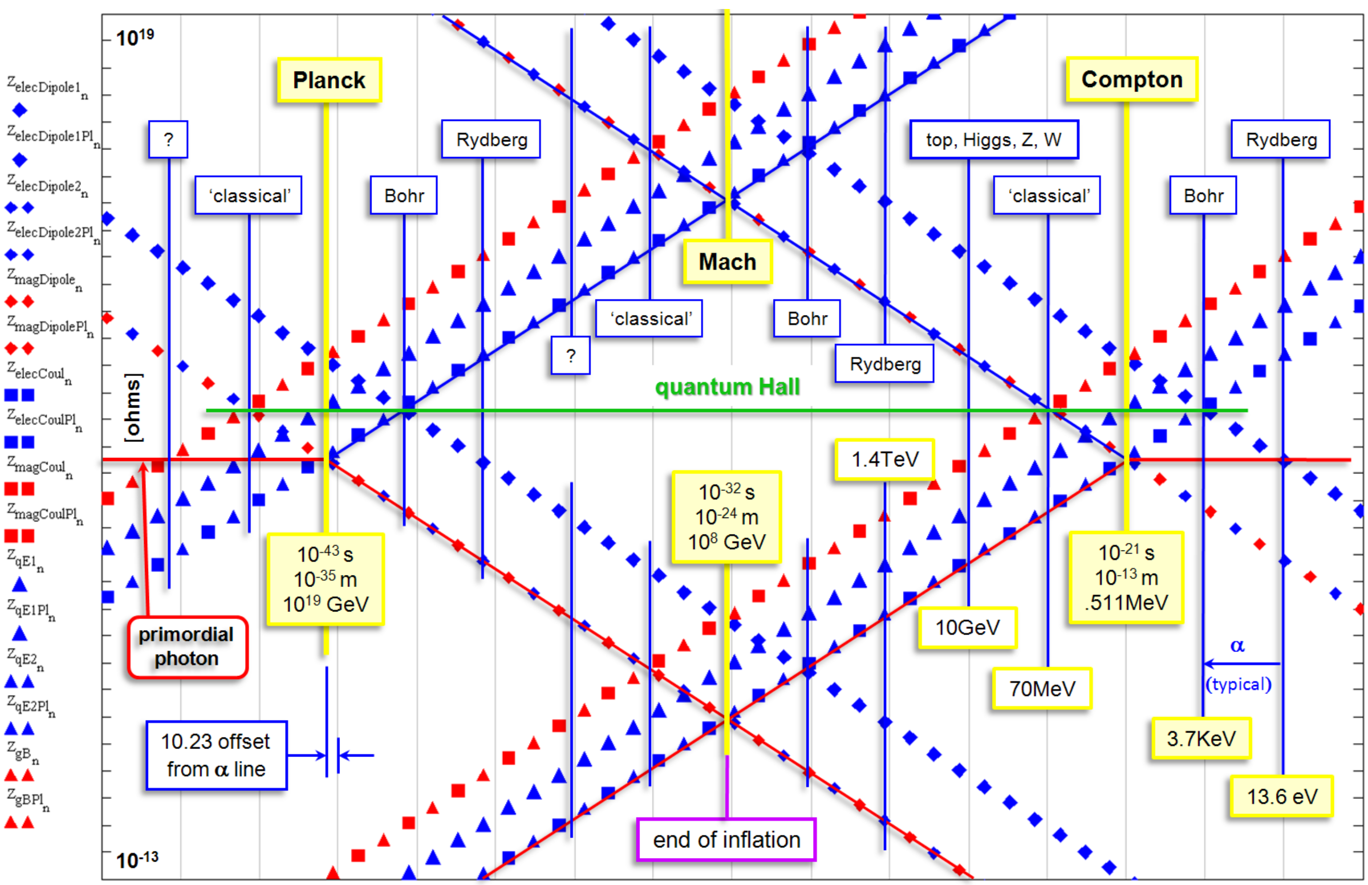

FIG. 5: A subset of interaction impedance networks of octonion wavefunctions defined at Compton and Planck lengths, showing a .511 Mev photon entering from right and 'primordial photon' from left. [52, 53, 57, 58]

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2.4 Transition Region Hawking Photon

Planck wavefunction event horizon is unstable, almost instantaneously radiates its energy as a Hawking photon. Impedance mismatches (figures 5 and 6) reflect back all but an almost infinitesimal fraction. At the Compton radius what is transmitted (gravitational mass)[52] precisely equals the .511 MeV electromagnetic self-energy of the electron wavefunction fields (inertial mass)[15, 59–61].

Reflection from mismatches yields the continuously increasing Hawking photon wavelength illustrated in figure 6, where the horizontal scale is logarithmic and vertical the ratio of field energy to mass gap. Hawking photon energy at the electron Compton wavelength is .511 MeV, precisely exciting the vacuum wavefunction. The progressively attenuated Hawking photon similarly resonates correspondingly smaller mass gaps at impedance nodes of successively greater wavelengths.

Point here is that observable universe is within the extreme near-field first cycle of transition Hawking photons radiated from Planck lengths of every massive particle in the universe. The consequent phase shift is what we call gravity. One might speculate that signs of the fields of figure 6 relate to sign of gravitational force. Initial phase of figure 6 was quasi-randomly selected, appears to suggest gravitation was repulsive for the first zeptosecond or so, peaks in attractive strength on solar system scale, and again becoming repulsive at a time far beyond present age of observable universe.

Timescale at Hawking and beyond is potentially interesting for astrophysics, question being whether 'dark energy' can be attributed to weakening attraction.

Timescale between Pauli and Einstein lengths is potentially interesting for CERN antimatter experiments. Model presented here suggests antimatter phase shift is opposite of matter, so gravitation will be repulsive. Antimatter flys up, and acceleration is time-dependent for brand-new accelerator antimatter.

And of course timescale between Planck and Compton is of interest to those who favor inflationary models.

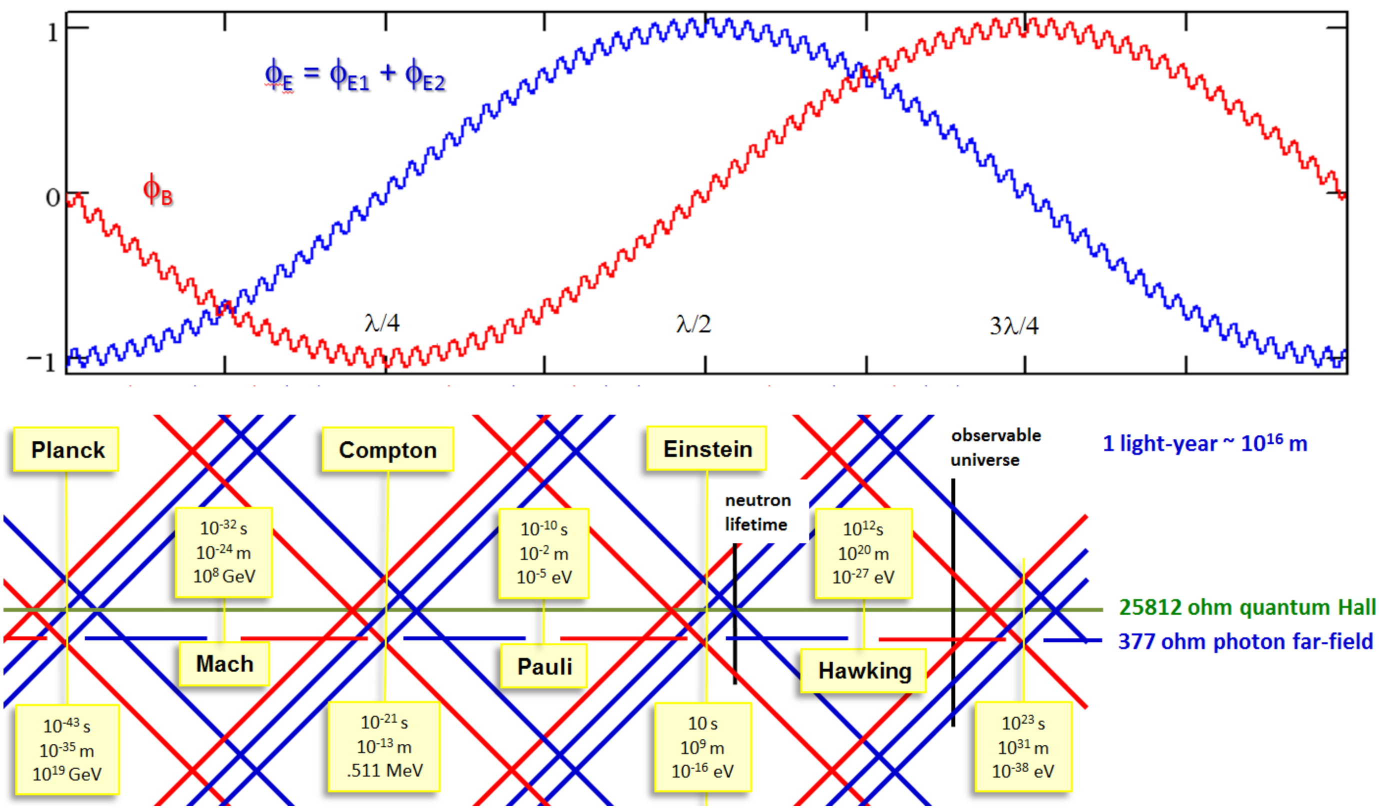

FIG. 6: Amplitude and phase correlation of Hawking photon radiated from Planck length with α-spaced nodes of the impedance network generated by octonion vacuum wavefunction mass gap excitation.
Planck and Compton wavefunctions appear to comprise a quarter-wave resonator.

3. FANO PLANE IN FLAT 4D MINKOWSKI SPACETIME

The Fano plane is a visual mnemonic for remembering octonion multiplication tables in a space of eight vector 'dimensions' (fig.7). As such it offers no information about the unique grade-changing property of the geometric product, but rather simply defines multiplicative orientations in an orthogonal 8D basis.

A first question is whether and how the mnemonic remains valid under the geometric product in a three dimensional space defined by one scalar, three vectors, three bivectors, and one trivector (fig.8).

There the one scalar is electron charge, defined negative in our world, determining the left-hand chirality indicated by the direction of arrows in figures 7 and 8.

In figure 8, the three vectors are grade 1 objects at corners of the triangle, three bivectors grade 2 objects on the circumference of the circle, and one trivector the grade 3 magnetic charge in the center.

Geometric grades of objects emerging from the products of figure 8 are shown boxed. On the circle we have the even subalgebra of the S-matrix 4D Dirac algebra, the eigenstates, what might be taken to be flavor SU3.

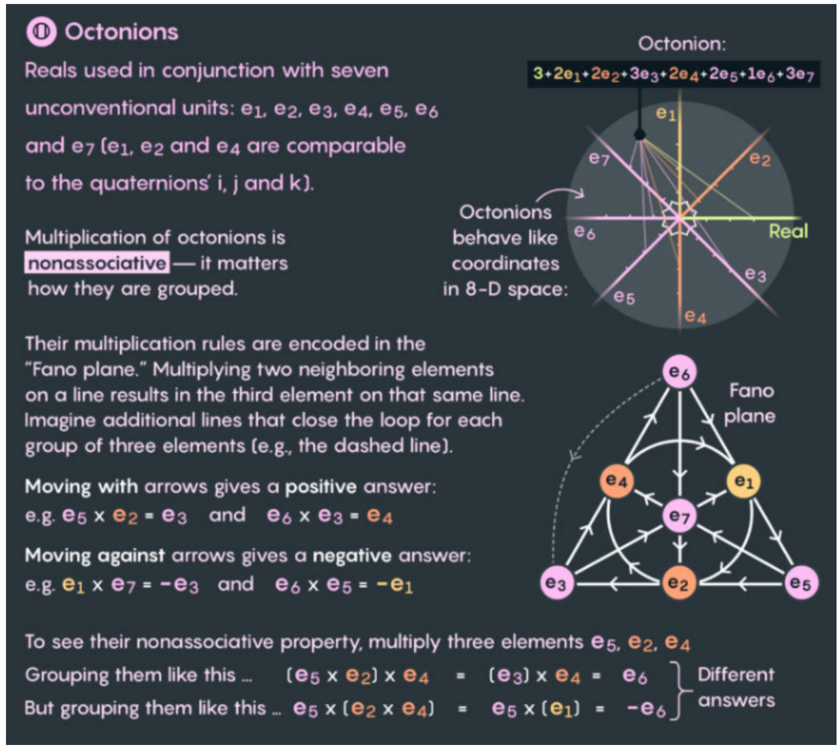

FIG. 7: Co-ordinate algebra of 8D octonion basis.[19]

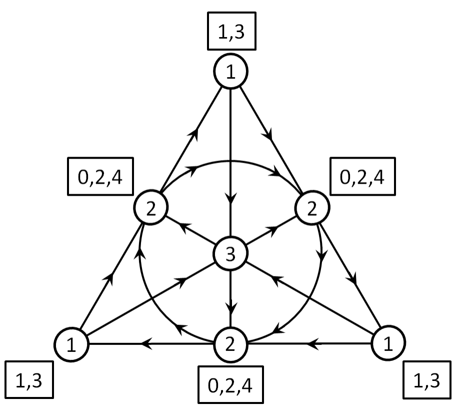

FIG. 8: Fano plane in 4D

At vertices of the triangle we have the odd modes, quite possibly the transition modes, color SU3. Weak interaction is three body, not explicitly represented in figure 8, although the absence of three-body associativity from the octonion algebra is likely related to chiral symmetry breaking and directions of the arrows.

While beyond the scope of the present essay, the role of topological symmetry breaking of magnetic charge should be mentioned here.

In figure 7 the basis vectors e3 and e4 are swapped. Similarly, in physical manifestation of the 3D Pauli algebra topological symmetry breaking swaps magnetic flux quantum (vector rather than bivector) with magnetic moment (bivector axial vector rather than true vector dipole) in the S-matrix.

To swap locations of a grade 1 vector boson and grade 2 spinor fermion pair in figure 8 would appear to significantly complicate the picture, a possibility beyond the present scope but perhaps worth further attention in discussions of supersymmetry and chirality.

4. SUMMARY AND CONCLUSION

Synthesis of two fundamental conceptual architectures **long lost in physics** - geometric representation of the wavefunction and impedance quantization of geometric wavefunction interactions - suggests that the octonion of string theory might more productively be viewed as orientational degrees of freedom of the geometric Pauli wavefunction of 3D space, rather than a collection of 1D oscillators in 8D space.

Such a phenomenology appears to permit direct connection between modern string theory and experiment, establishing long overdue and much needed relations between math, physics, and philosophy.

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