Naturalness Revisited: ~~Spacetime~~ Spacephase

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What defines the boundary of a quantum system is phase coherence, not time coherence. Time is the same for all three spatial degrees of freedom in flat 4D Minkowski spacetime. However, in the quantum mechanics of wavefunctions in 3D space, phases of wavefunction components are not necessarily the same in all three orientations. Consequently, the S-matrix generated by the geometric Clifford product of two 3D wavefunctions exists not in 4D spacetime, but rather in 6D 'space**phase**'.

Spawning from Copenhagen, almost a century of proliferating interpretations of quantum mechanics suggests that, at the most fundamental level, present day quandries in particle physics and cosmology[1–9] are all about the enigmatic unobservable wavefunction[10–12]. At the foundation of quantum mechanics is the vacuum wavefunction. To have hope of untangling present theoretical perplexities one must begin there, with a maximally natural wavefunction[13].

The language of quantum mechanics is Clifford algebra, known to most physicists in the matrix representation of Dirac. For present purposes the more intuitive geometric representation is to be preferred, the algebra of interacting geometric objects[14–23]. The full eight-component vacuum wavefunction shown at top and left of figure 1 is comprised of one scalar, three each orthogonal vectors and bivectors, and one trivector - the fundamental geometric objects of Euclid. These define the octonion[24–26], lacking only associativity to be a minimally complete Clifford algebra of 3D space; arguably a maximally natural vacuum wavefunction.

Geometric Algebra is topological, changes dimensionality[27]. In GA one refers to dimensionality as grade[28], reducing the possibility of confusion with degrees of freedom. Interaction of two wavefunctions is modelled by the geometric product, the sum of grade-reducing dot and grade-increasing wedge products[29]. For example, the product of two 1D vectors is a 0D scalar and a 2D bivector.

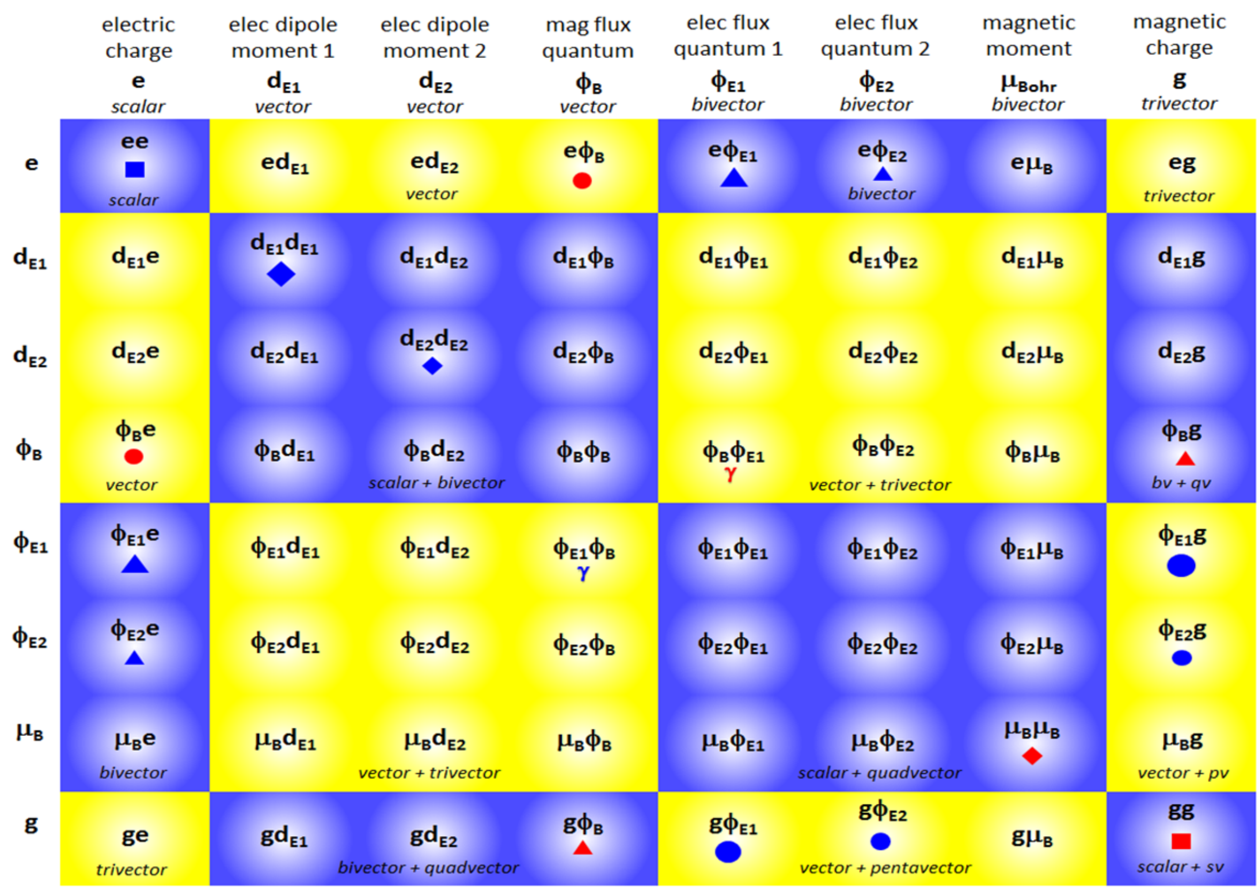

FIG. 1: Impedance representation[30–32] of the S-matrix[33–36] arranged in even eigenmodes (blue) and odd transition modes (yellow) by geometric grade. Modes indicated by colored symbols are plotted in figure 2.

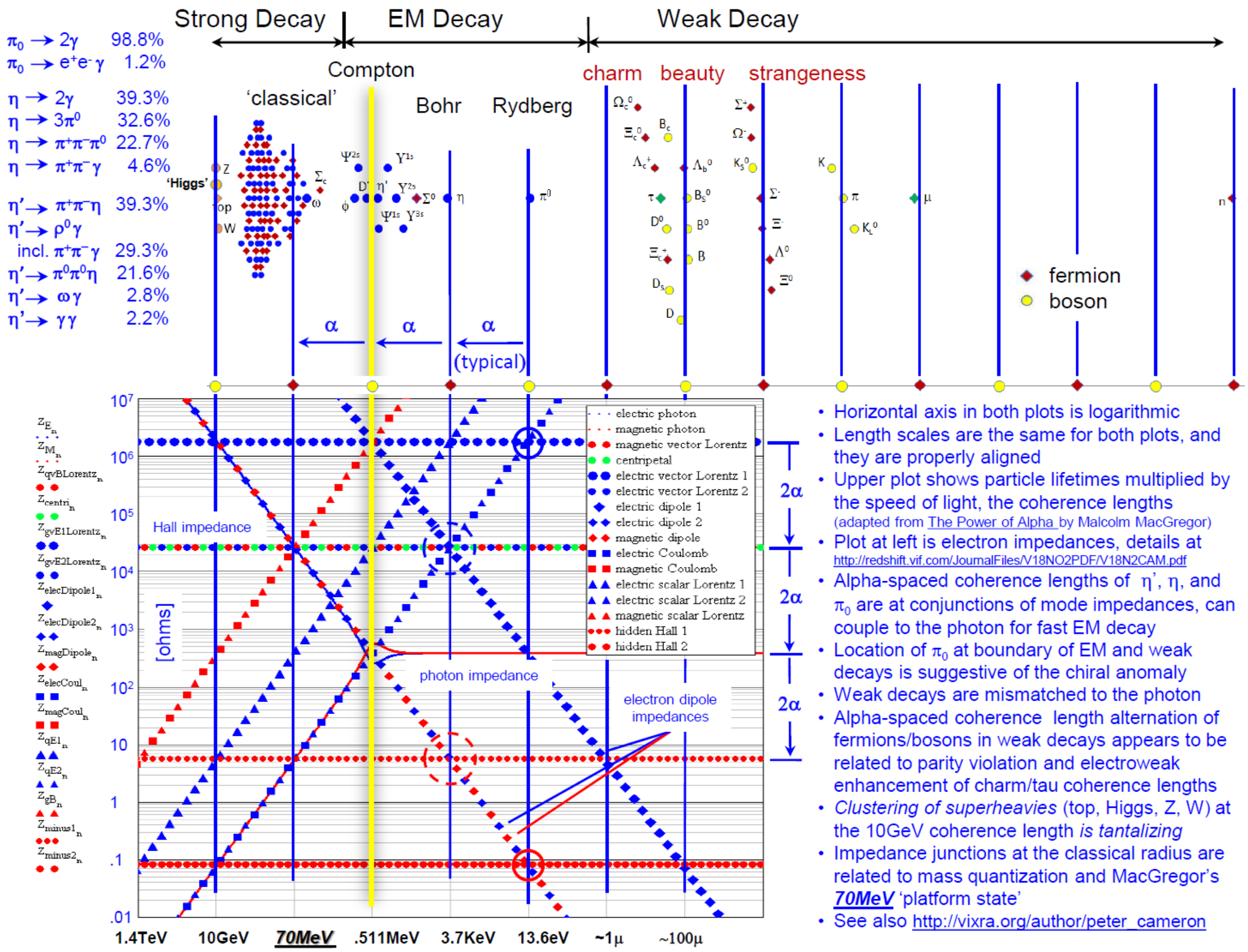

FIG. 2: Modes indicated by colored symbols in figure 1 are plotted in the impedance network at lower left. Phase correlation of unstable particle causal lifetimes/light cone coherence lengths [37–39] with impedance nodes of the network follows from the fact that impedances must be matched for the energy transmission essential in decay[40].

Physical manifestation of the vacuum wavefunction model is realized by introducing the dimensionless (gradeless?) electromagnetic coupling constant

$$\alpha = \frac{1}{4\pi\epsilon_0}\frac{e^2}{\hbar c} \approx 0.0073 \qquad 1/\alpha \approx 137 \tag{1}$$

Combinations of the four fundamental constants that define α permit assigning topologically appropriate quantized electric and magnetic fields to the eight components of the vacuum wavefunction[41].

Given that wavefunction fields are quantized in any quantum field theory, it is unavoidable that impedances of wavefunction interactions will likewise be quantized. *This is important:* Impedance matching governs amplitude and phase of information transmission, of the flow of energy[42].

The need of any model for the essential quantum phase information shown on the horizontal axis of figure 2 drove unsuccessful attempts at analytic continuation and abandonment of the S-matrix bootstrap of the 1960s, and remains the obstacle blocking reduction of string theory's ten degrees of freedom. Wavefunction collapse yields an amplitude and loses a phase. Dimensional (grade) reduction yields a phase and loses an amplitude.

In the model presented here[13] this essential phase information comes down from higher grade components of the S-matrix - the quad, penta, and sextavectors. It remains that the relative phases are unknown. However, phase correlation between lifetimes and impedance nodes of figure 2 gives connection to the physical world that may permit convergence of an iterative model. If time symmetry applies, excitation of the mass gap[43] at the electron Compton wavelength generates the elementary particle spectrum[44].

Such a model has the full symmetry between space and 'time' that is essential in quantum mechanics - three space, three time - where time is understood to be the integral of phase. Welcome to spacephase.

Glossary (In order of logical progression)

geometric algebra - geometric representation of Clifford algebra; the algebra that defines addition, subtraction, multiplication, and division of fundamental geometric objects - point, line, plane,...

geometric grade - connotes dimensionality in GA, avoiding conflation of dimensions with degrees of freedom.

geometric product - sum of the grade-reducing dot and grade-increasing wedge products. Grade-increasing operations break topological symmetry. One can smoothly transform line into point, but not point into line.

vacuum wavefunction - wavefunction that exists in the absence of fields; pure geometry.
The eight component geometric Clifford algebra of 3D space - one scalar point, three vector line elements, three bivector area elements, and one trivector volume element.

wavefunction fields - topologically appropriate quantized E and B fields are calculated from the four fundamental constants defining the dimensionless coupling constant α, and assigned to the eight vacuum wavefunction components.

naturalness - dimensionless ratios between free parameters or physical constants appearing in a physical theory should take values of order one, with free parameters not fine-tuned, in a minimal definition.

dimensionless - pure number, defined as products and/or ratios of quantities having units that cancel. Photon-electric charge coupling constant $\alpha \approx 0.0073$ is dimensionless. Its topological dual, the trivector magnetic component, couples as $1/\alpha \approx 137$. Their product is unity, the full electromagnetic coupling constant.

maximally natural wavefunction - one whose geometry and fields are familiar, intuitive. One that possess a variety of desired properties, including but not limited to fine-tuning and dimensionlessness.

wavefunction interactions - modelled by the geometric product.

impedance - that which determines amplitude and phase of information transmission, of the flow of energy, in wavefunction interactions. A fundamental concept, long overlooked in QED.

impedance matching - what matters in wavefunction interactions are not absolute values of impedances, but rather whether they are matched, numerically equal. In this impedances are like the energy whose flow they govern; what matters are not absolute values, but differences in energy.

phase - relative difference in zero crossings of two signals; not a single measurement observable, a distinction of fundamental importance in seeking to understand the paradoxes of quantum interpretations.

phase coherence - two wave sources are perfectly coherent if they have the same waveform and frequency and a constant phase difference. Electron and positron spinors of Dirac wavefunction are an example of self-coherence. Coherence defines the boundary of a quantum system.

wavefunction collapse - wavefunction interaction impedances shift phases of the coupled modes that comprise the wavefunctions, in the limit decohering one or both. With decoherence, phase is no longer meaningful. What remains is the amplitude, a lump of incoherent heat.

dimensional reduction - changes in geometric grade are topological. Topological potentials are inverse square, can do no work, communicate only phase, not a single measurement observable.

analytic function - one that is smooth and continuous, differentiable at every point.

analytic continuation - analyticity permits extending a function to the complex plane, to gain information about the unobservable quantum phase needed to model wavefunction interactions, to connect with the experimentalists.

S-matrix - the scattering matrix connects initial and final states of wavefunction interactions. Given that amplitude and phase of interactions are governed by impedances, impedance representation of the S-matrix most comfortably satisfies requirements of naturalness.

spacephase - extension of spacetime to the 'space' of quantum mechanics, comprised of three each spatial and phase degrees of freedom. Working in natural 6D spacephase fully restores symmetry between space and time (the integral of phase) introduced by special relativity and the Dirac equation.

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In memory of Al Wright, as fine a physicist as one might hope to meet.

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Branching ratios of π_0, η, and η' are calculated from impedance matching, perhaps a good place to start an interative computational analysis of mass gap excitation.