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Bootstrapping the Muon Collider: Massless Neutrinos in the g-2 Delivery Ring

The impedance model opens an old window on the roots of string theory via the S-matrix bootstrap. There is no Lagrangian. Equations of motion calculate mode impedances of the S-matrix. These govern amplitude and phase of energy transmission, such that the S-matrix impedance representation is also the gauge group, with direct interaction of both flavor and color matrix elements the citizens of Chew's 'nuclear democracy'. Naturalness comprises the consistency conditions[1]. The model requires just three assumptions - geometry, fields, and a mass gap - is finite without renormalization, and appears to be maximally analytically continued. There are no free parameters. It suggests a simple proof-of-principle experiment in the Fermilab muon g-2 delivery ring, demonstrating both massless oscillation and possibility of low-energy Muon Collider lifetime enhancement, complementary to high-energy time dilation of the Lorentz transform[2].

[1]https://www.researchgate.net/publication/335240613_Naturalness_begets_Naturalness_An_Emergent_Definition [2]https://www.researchgate.net/publication/359592916_Bootstrapping_the_Muon_Collider_Massless_Neutrinos_in_the_g-2_Delivery_Ring

The abstract – three points impedances evnman parameter Provenance - the S-matrix Bootstrap Bjorken 1959 S-matrix Impedance model opens a window on roots of string theory via the 1960s S-matrix bootstrap. There is no Lagrangian. maser impedance Equations of motion calculate S-matrix element mode Feynman 1963 impedances. These govern amplitude and phase of energy Weyl 1918 transmission, such that the S-matrix is the gauge group, Regge poles 1959 D lattice match with direct interaction of both flavor and color matrix elements the citizens of Chew's 'nuclear democracy'. The London, Weyl model appears to provide maximal analytic continuation 1922-1929 quantum wire Naturalness comprises the consistency conditions. The model – three assumptions Yang-Mills 1954 dual resonance model a. geometric representation of Clifford algebra (1,3,3,1) Veneziano 1968 b. four fundamental constants that define α mechanical impedance c. mass gap – electron Compton wavelength Mach's principle 1975 V-A Feynman, Proof-of-Principle experiment Gell-Mann 1958 string models a. supported by an accurate calculational model Schwarz and Scherk, Nambu, Ramond,... b. ~10 tesla-m solenoid in the Delivery Ring Weinberg c. parasitic lifetime measurement in g-2 ring 1928 Salam 1968 von Klitzing 1985 d. demonstrates low-energy muon lifetime enhancement e. validates massless neutrino models Standard Model shift to Planck 1974 length 1974

https://www.youtube.com/channel/UCNpqlfJpfVen0ULQ-k9JwQQ

independent timelines – reality is a network

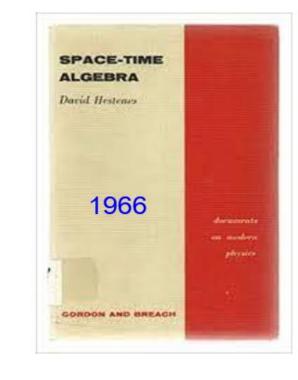
generalized quantum

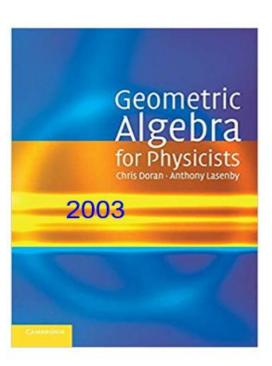
no Higgs mass here?

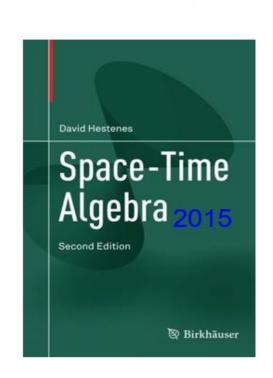
Division Algebras - add, subtract, multiply, divide

- division is essential for invertibility (... topology, singularities, dark matter, T-duality, ...)
- there exist four normed division algebras real, complex, quaternion, octonion

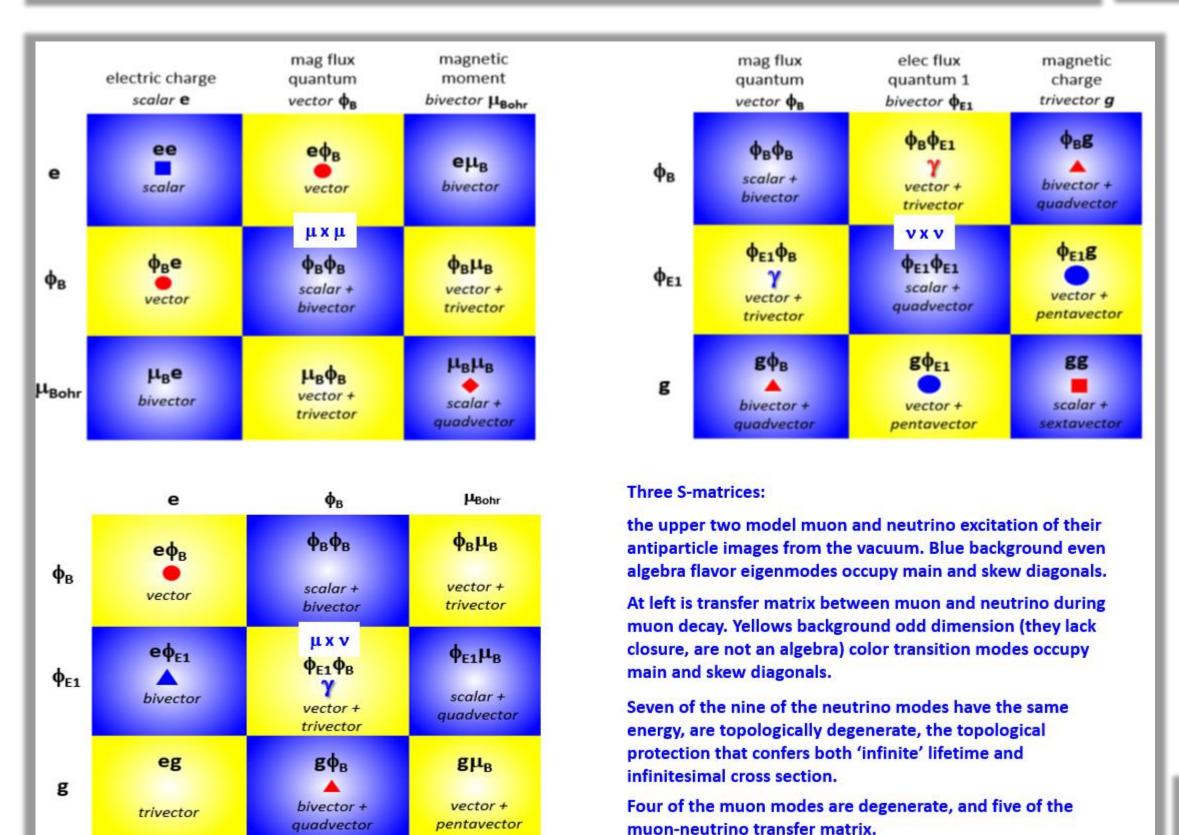
 Hurwitz
- these are Clifford algebras, more familiar in Pauli and Dirac matrix representations
 Pauli matrices are basis vectors of 3D space in GA
- Dirac matrices " " 4D spacetime
- eight-component 3D Pauli algebra is minimally and maximally complete
- the 'natural' vacuum wavefunction of quantum mechanics the same at all scales







http://geocalc.clas.asu.edu/pdf/SpacetimePhysics.pdf



Generalized Quantum Impedances: A Model for the Unstable Particles

Peter Cameron*

Brookhaven National Laboratory
Upton, NY USA 11973

(Dated: June 20, 2012)

The discovery of exact impedance quantization in the quantum Hall effect was greatly facilitated by scale invariance. Both follow from the application of the Lorentz force to a two dimensional ballistic current carrier. This letter speculates upon the possibility that quantum impedances may be generalized, defined not just for the Lorentz force, but rather for all forces, resulting in a precisely structured network of scale dependent and scale invariant impedances. If the concept of generalized quantum impedances correctly describes the physical world, then in quantum physics such impedances govern how energy is transmitted and reflected, how the hydrogen atom is ionized by a 13.6eV photon, or why the π_0 branching ratio is what it is. An impedance model of the electron is presented, and explored as a model for the unstable particles as well.

"Geometric Algebra is the universal language for mathematical physics" by AAPT division 300 BC Synthetic Geometry The 2002 Oersted Medal Syncopated Algebra omplex Variables Diophantes was awarded to **David Hestenes** (First printing \ by the American Physical Society for Analytic Geometry Descartes "Reforming the mathematical language of physics" Complex Algebra Wessel, Gauss Extensive Algebra Quaternions grade increasing Grassmann Hamilton 1854 Matrix Algebra Vector Calculus Determinants Ricci Differential Forms E. Cartan dot product - grade decreasing Spin Algebra Pauli, Dirac dynamic susy! Geometric Algebra & fermions to bosons, bosons to fermions Calculus Given two vector bosons W and Z, the product WZ changes grades. In the product WZ = W·Z + W^Z,

two grade 1 vector bosons transform to grade 0 scalar boson and grade 2 bivector fermion WZ = Higgs + top

Taken together, the four superheavies comprise a minimally complete

2D Clifford algebra – one scalar, two vectors, and one bivector

sum mode $m_Z + m_W = m_{top}$

difference mode $m_Z - m_W = m_{bottomonium}$

Mechanical analog of the Dirac equation

Suspension

Suspension

Suspension

Vibration isolator (spring suspension unit)

Hydraulic power hoses

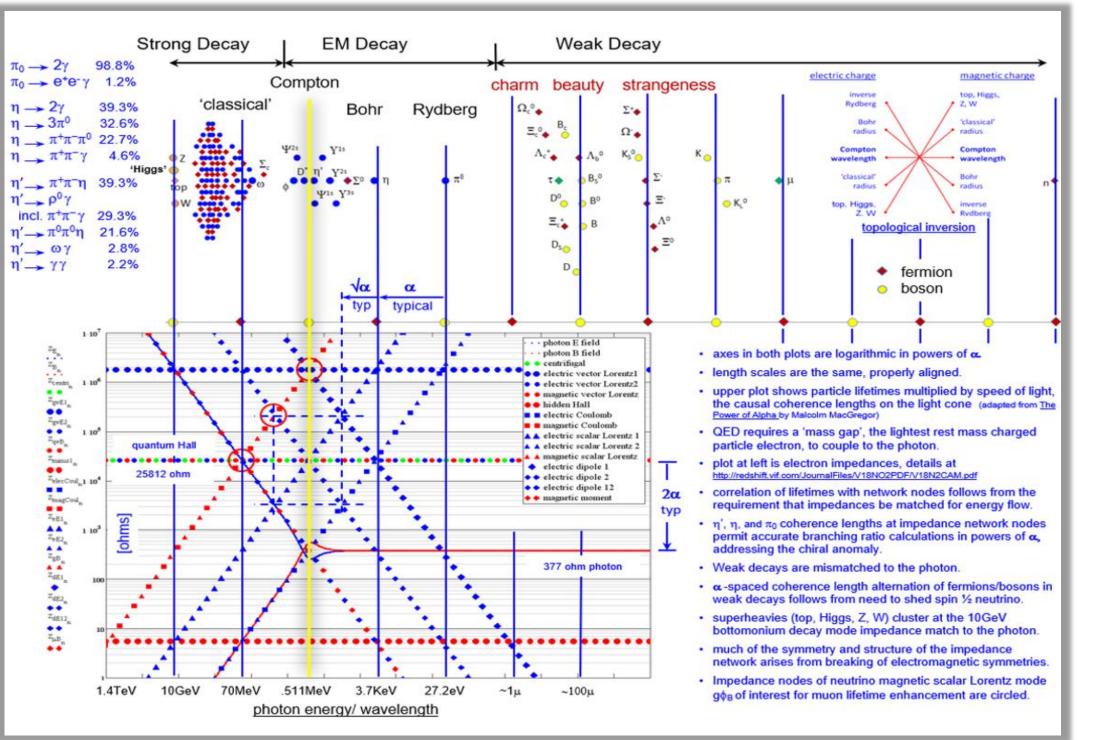
Synchronous counter-rotating eccentrics transform 2D rotation to 1D translations, are an analog to electron and positron spinors of Dirac equation counter-rotating in phase space.

A typical vibratory piledriver generates a sinusoidal inertial force of many tens or hundreds of tons, might be thought of as an `inertia wave generator'. Given equivalence of gravitational and inertial

mass, it might also be called a gravitational wave generator.

The extent to which such a toy model might ultimately prove useful remains to be seen. For now it seems clear that it provides a simple shortcut to calculating quantized electromagnetic impedances

this is important – impedance matching governs amplitude and phase of energy transmission



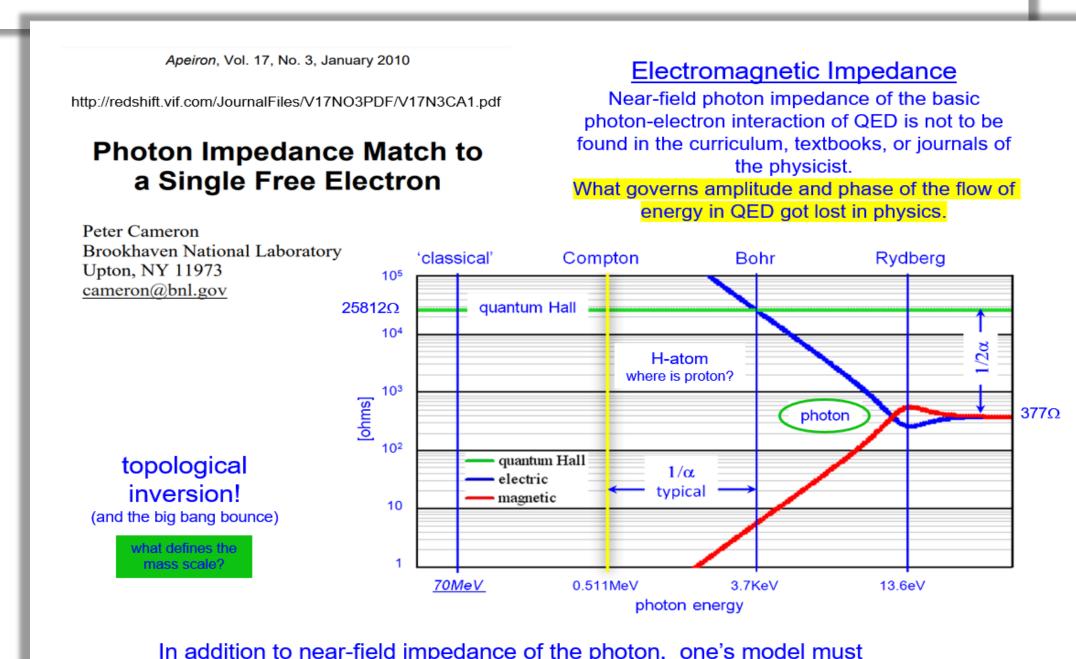
Outline

- theoretical minimum geometry, fields, and a mass gap
 - geometry Clifford algebra vacuum wavefunction (1,3,3,1)
 - the geometric S-matrix
- fields electromagnetic coupling constant $oldsymbol{lpha}$
- the minimally (and maximally) complete QED S-matrix
- mass gap lightest rest mass charged particle (the electron) to couple to the photon
- impedance matching governs amplitude and phase of energy transmission
- mechanical impedance topological inversion in SI units
- unstable particle spectrum nodes of the quantized impedance network
- parametric impedances noiseless nonlinearity essential in QM
- neutrino wavefunction and the 2D S-matrix calculating coherence lengths
- 3D S-matrix Rubik's cube
- motivation massless neutrinos and the Muon Collider

https://www.youtube.com/channel/UCNpglfJpfVen0ULQ-k9JwQQ youtube channel fills in the gaps

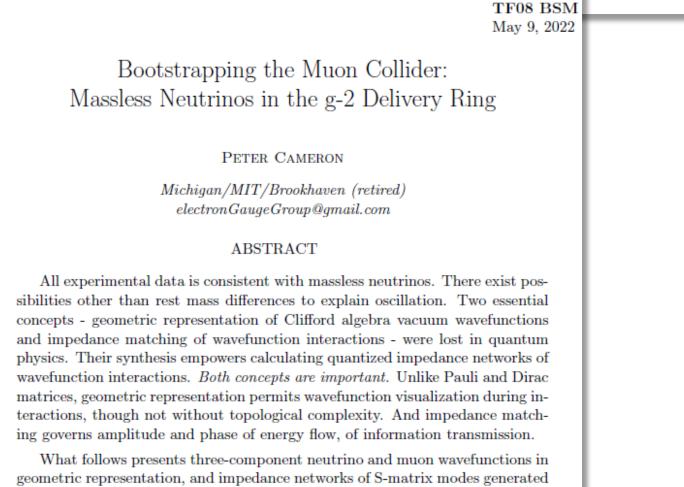
blue background = even dimension algebra = flavor eigenmodes yellow background = odd dimensions algebra = color transition modes

Pauli σ matrices are basis vectors of 3D space, Dirac γ matrices those of 4D spacetime



include the corresponding quantized near-field impedance of the electron.

A second piece of the puzzle that got lost in physics.

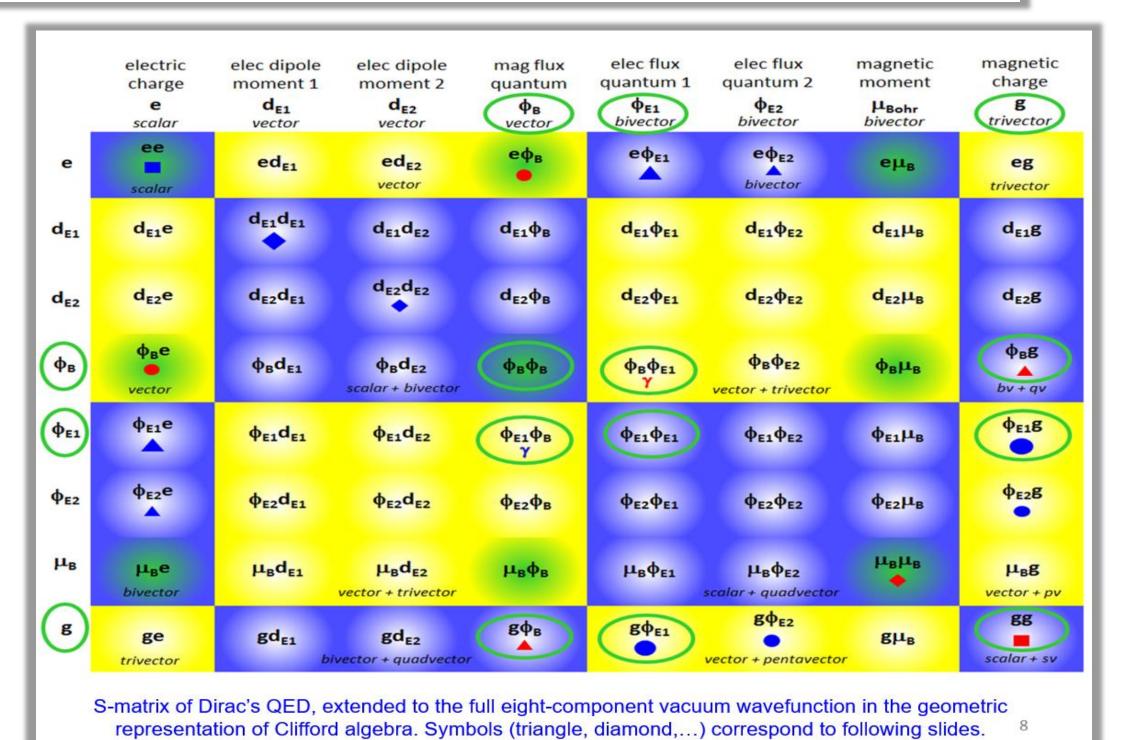


What follows presents three-component neutrino and muon wavefunctions in geometric representation, and impedance networks of S-matrix modes generated by wavefunction interactions as modeled by spatial dimension-changing Clifford products. This permits massless neutrino oscillation via self-excited vacuum impedance phase shifts, both geometric and topological. It suggests we get real, step beyond model and theory with a simple proof-of-principle experiment in the Fermilab muon g-2 Delivery Ring. It offers the possibility of demonstrating both massless oscillation and low energy muon lifetime enhancement, complementary to Muon Collider relativistic time dilation at high energy.

"The hard part will be getting physicists to think in terms of impedances" Richard Talman, walking to lunch at Brookhaven cafeteria (April 2012)

Submitted to the Proceedings of the US Community Study on the Future of Particle Physics (Snowmass 2021)

The Theoretical Minimum Three assumptions – geometry, fields, and 'mass gap' geometric quantization point, line, plane, volume Pauli σ matrices are basis vectors of 3D space, Dirac y matrices those of 4D spacetime https://www.youtube.com/watch?v=60z_hpEAtD8 3D Pauli algebra 1 scalar, 3 vectors, 3 bivectors, 1 trivector Clifford algebra in geometric representation vacuum wavefunction the same at all scales electromagnetic quantization five fundamental constants metric = mass gap = m_e $e, \varepsilon_0, c, h, m_e \leftarrow$ $\alpha = \frac{1}{4\pi\epsilon_0} \frac{e^2}{\hbar c} \approx 0.0073$ wavefunction .vavefunction Clifford product 4D Dirac algebra S-matrix of observables



no free parameters

- emergence



mean more mass flow. However more impedance means less flow. Thwarted Bjorken, Feynman,...

2. concept of **exact** impedance quantization did not exist until

concept of exact impedance quantization did not exist unonKlitzing et.al discovered QHE in 1980.
 OHE was easy – scale invariant!

QHE was easy – scale invariant!
 habit of setting fundamental constants to dimensionless unity h = c = G = Z = ... = 1 let Z slip over the horizon.

6D phase space

Mismatches are Feynman's regularization parameters of QED.

Inclusion renders QED finite. This is what Bjorken discovered back in 1959, anticipated it would be a powerful tool, was led astray by the inversion of SI units. Feynman had an EE student do a thesis on impedance matching to the maser.

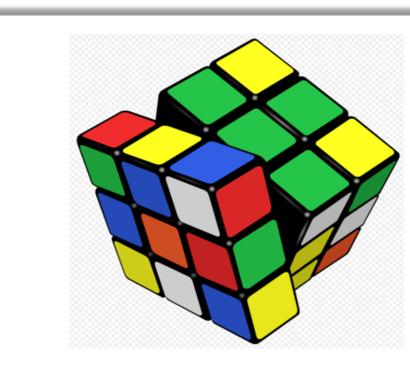
Bjorken was perhaps not familiar with their work when writing his 1959 thesis [46]. In that thesis is an approach summarized [47] as "...an analogy between Feynman diagrams and electrical circuits, with Feynman parameters playing the role of resistance, external momenta as current sources, and coordinate differences as voltage drops. Some of that found its way into section 18.4 of..." the canonical text [48]. As presented there, the units of the Feynman parameter are [sec/kg], the units of mechanical conductance [5].

J. Bjorken, and S. Drell, Relativistic Quantum Fields, McGraw-Hill, section 18.4 (1965)

coordinate differences as voltage drops.
and its way into section 18.4 of..." the

]. As presented there, the units of the ter are [sec/kg], the units of mechanical

J. Bjorken, "Experimental tests of Quantum electrodynamics and spectral representations of Green's functions in perturbation theory", Thesis, Stanford (1959) http://searchworks.stanford.edu/view/2001021
J. Bjorken, private communication (2014)



Rubik's Cube group https://en.wikipedia.org/wiki/Rubik%27s_Cube_group

manipulations of the cube form the

Rydberg

radius

wavelength

top, Higgs,

One of the black hole event horizon

impedances is the 25812 ohm quantum Hall.

🎤 Z, W

radius

radius

inverse

Rvdberg

'classical'

wavelength

One can imagine labeling the faces with S-matrix modes of the three-component wavefunction of interest, be they neutrino or muon wavefunction interactions with the image wavefunctions they excite from the vacuum, or S-matrix of muon with neutrino during muon decay.

The central mode of each face for a given wavefunction is of particular interest, as it appears invariant under cube manipulations.

Phase coherence at all edges can be thought of as maximal analytic continuation of the bootstrap.

Summary

All experimental data is consistent with massless neutrinos. There exist possibilities other than rest mass differences to explain oscillation. We presented an outline of such a possibility, grounded in two essential concepts lost in physics – geometric representation of Clifford algebra and quantization of wavefunction interaction impedances.

thank you

What motivated this investigation was the desert at the LHC – but one Higgs and no susy – and the search for the next big machine, perhaps the muon collider.

Please see the youtube channel for more detail.

https://www.youtube.com/channel/UCNpglfJpfVen0ULQ-k9JwQQ