Causal Set Theory and the Origin of Mass-ratio

Carey R Carlson, June 27, 2010

Abstract

Quantum theory is reconstructed using standalone causal sets. The frequency ratios inherent in causal sets are used to define energy-ratios, implicating the causal link as the quantum of action. Space-time and its particle-like sequences are then constructed from causal links. A 4-D time-lattice structure is defined and then used to model neutrinos and electron clouds, which together constitute a 4-D manifold. A 6-D time-lattice is used to model the nucleons. The integration of the nucleus with its electron cloud affords calculation of the mass-ratio of the proton (or the neutron) with respect to the electron. Arrow diagrams, along with several ball-and-stick models, are used to streamline the presentation.

Ideas must have formal expression to become part of physics. In order to formalize Whitehead's idea of "temporal succession," a temporal successor relation is required. Ordered-pair notation suits the purpose. A single step of succession is denoted by a single ordered pair: (a,b). The arguments denote individual moments of time. A two-step sequence is denoted by a set of two ordered pairs with one member in common: {(a,b), (b,c)}. Any finite temporal structure can be denoted by such an interlinked set of ordered pairs.

Next we make use of the successor relation to define *earlier than*:

1. For any two moments, if (a,b), then a is also *earlier than* b.
2. For any three moments, if a is *earlier than* b, and b *earlier than* c, then a is *earlier than* c.

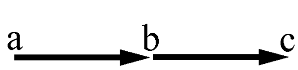
We then characterize time order with a postulate:

No moment can be *earlier than* itself.

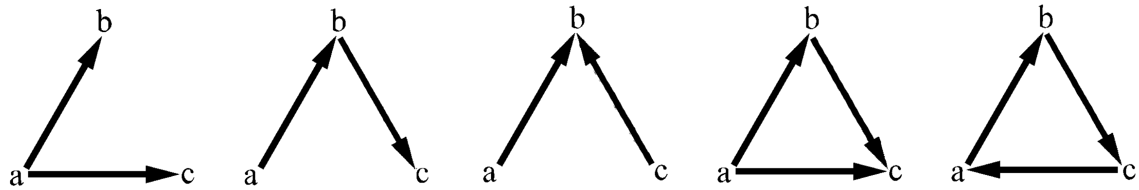
We now set out to reconstruct physics from time order alone. We purposely neglect to provide any axiom of infinity. Any construction we perform is thus confined to a finite number of ordered pairs. Any subsequent analysis into whole-and-part will therefore arrive at logical primitives in a finite number of steps. The only primitives are the moments, along with instances of the successor relation. In consequence of this whole-and-part finitude, there is no infinite divisibility of a time interval, no continuous manifold, and no calculus in the theory.

A graphic arrow, with its directional asymmetry, serves just as well as an ordered-pair expression to depict a temporal transition from one moment to another. We can use the argument letters to label the endpoints of the arrow:

We can depict a time series of three moments as follows:



We can construct a time series of any finite length we like, but we can also construct time sequence possibilities that are *not* serial. There are four distinct ways that three moments can be arranged in chronological order. These are diagrammed below, along with one "impossible figure" which violates chronology protection.



The offending diagram is the one on the far right, because each moment is earlier than itself. The first four diagrams are fine, and we assign them common names, from left to right: *fork*, *series*, *convergence*, *triangle*. Each diagram gives rise to variations if we swap the labels around while leaving the arrows undisturbed. It is *structure*, as defined by isomorphism, that remains undisturbed by the label swapping. The variety of structure provides the variety of physical entities in this theory. The formal basis yields a limited variety of structural possibilities for a finite number of moments. That "limited variety of natural kinds" provides a basis for the application of probability theory. However, the theory is founded on the enumeration of all structural possibilities, starting with the simplest ones shown above, and probability has no part in this.

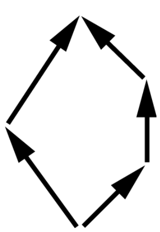
There is only one distinct diagram with exactly one arrow. There are three distinct diagrams of two arrows, counting the *fork*, *series* and *convergence*. The *series* surprises no one, since it is nearly an automatic assumption that time order is strictly serial. The *fork* and *convergence* contravene that assumption. Time order and causal order are conflated in this theory, such that "temporal succession" and "causal succession" are interchangeable terms. Any *fork* in the time diagrams thus depicts a single cause with multiple effects, and any *convergence* depicts a single effect with multiple causes.

Causal Set Theory

Our formal basis is the same as that of *causal set theory*. The choice of terminology to accompany the arrow diagrams is flexible. I favor the terms "moment" and "transition" for the two primitives of the theory. Causal set theorists use the terms "elements" and "causal links," respectively, for the same two primitives. In the diagram notation, these terms correspond to the junctions (or nodes) at which the arrows meet, and the arrows themselves, respectively.

The Origin of Mass-Energy

The *triangle* diagram consists of two locally separable paths that begin together and end together. A *relative frequency ratio* is formed, which compares a 2-step path and a single-step path that traverse the same time interval. Without the structural feature of forking paths that rejoin, relative frequency does not arise. The time triangle is thus the simplest causal set to feature an inherent relative frequency. We can construct a diagram of relative frequency for any rational number. The following diagram features a 2:3 relative frequency ratio:



Relative frequencies serve this theory as relative energies in accord with Planck's E=hf. Two energy values for comparison, E1 to E2, correspond to hf1 and hf2 respectively. Thus, E1/E2 = f1/f2. (Planck's constant drops out.) This suggests that an energy ratio is just a frequency ratio, and that energy only arises, and only has meaning, in ratio-comparison form. In regard to frequency, all that we can glean from the above diagram is the ratio of arrow-count for two locally separable time pathways. The 2:3 ratio measures the *energy ratio* of the one path to the other. The individual arrows are the countable units that yield the integer components of the numerical ratio. By that consideration, the individual arrows of our diagrams depict the individual quanta of quantum theory. Energy is packetized in quantum theory. Here, the flow of time is itself packeted into discrete transitions, and these serve the theory as quanta of action.

Empirical measurement procedures are also confined to ratio-comparisons, as many astute theorists have pointed out. We measure one mass against another, one spatial span against some chosen yardstick, one time interval against some *de facto* unit of time, or one frequency against another (as with the interferometer.) The structural definition of relative frequency in this theory provides the ontological ground for the ratio-comparison constraint that characterizes practical measurement techniques. We tend to employ an arbitrary unit of measure, then forget that we are doing so, and think of energy as having an absolute value of scalar quantity. We then wonder about "the origin of mass." The answer is not to be found in the origin of a scalar quantity, but in the structural origin of discrete ratios that arise in patterns of sheer temporal succession. This account of the structural origin of mass-ratio will bear fruit in the developments ahead. We shall first construct the electron, then the proton, and then derive 1:1836 as their mass ratio. The derivation of the ratio proceeds without obtaining any scalar mass value for either particle alone, illustrating the point that's just been made.

The reciprocal of frequency is wavelength. Higher frequencies equate to shorter wavelengths. In temporal terms, wavelength is a measure of duration, or time period. Higher frequency paths consist of shorter-period quanta. Frequency ratios and their reciprocals thus measure energy and wavelength ratios, respectively. We obtain the numbers that physics requires for frequency and wavelength without invoking either waves or particles.

Defining "closed diagram" and "bounded region of time"

Some diagrams have a single earliest moment and a single latest moment. Such a diagram shall be termed "closed." A diagram that is not closed is termed "open."

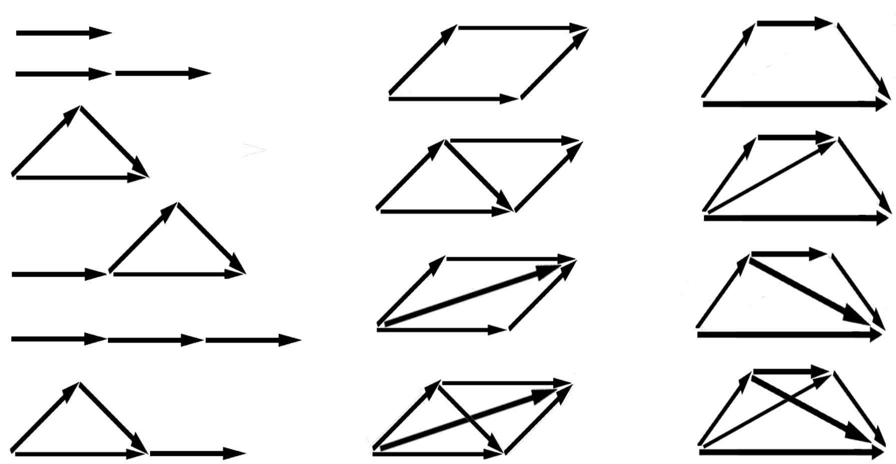
A "bounded region" is defined as "the ordered complex of all the quanta located between two defining moments, one earlier than the other." The two defining moments are the earliest and latest moments depicted in the closed diagram of the region. Such causal boundedness characterizes what can be learned by the scientific method. The causal patterns that play out in the runtime of an experiment are localized by two bounding moments: the moment of initiation, when the causal laws being tested are triggered into action; and the moment of completion, when the outcome of the experiment is known. Between those two moments, nature enacts a causal sequence that culminates either at the predicted outcome or at some other outcome.

Closed diagrams will also assume special importance in the modeling of stable particles and the calculation of their mass ratios.

Our causally connected universe, we must suppose, corresponds to one elaborate arrow diagram. What are its highest and lowest frequencies? In a *bounded region*, the frequency range is capped at both ends. This ensures that energy density is everywhere finite. In the region of a high-energy experiment, we produce higher frequencies than those of ordinary matter in a livable environment. Confining scope to the latter, the up/down quarks contain the quanta of highest frequency and least time period. That marks the high end of nuclear frequencies in ordinary matter. From there, a ladder of discrete lower frequencies extends to the frequency of a free electron. The EM spectrum begins there, and extends to lower and lower frequencies, finally fading out of detection due to increasingly feeble quanta. The low end of the frequency spectrum, corresponding to quanta of the longest time period, is limited, if at all, by the age of the universe. (The age of the universe is not necessarily finite on this theory.)

The diagram notation is interchangeable with the ordered-pair notation we began with. Any diagram can be labeled at its nodes and each arrow then translated to an ordered pairing of the labels at its endpoints. The theory can be expressed entirely as the combinatorics of ordered-pair expressions. That is the safeguard against over-interpretation of the diagrams. Shape and size of the diagrams are irrelevant artifacts of planar geometry that indicate nothing in the domain of reference. A diagram specifies nothing but time order. That said, we can streamline the presentation by relying on the diagrams for the more intuitive recognition of structure that they provide.

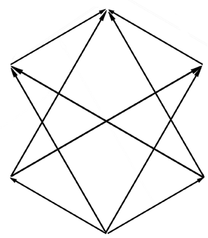
Confining attention to closed diagrams, here is a complete set of the closed diagrams that employ four moments or less:



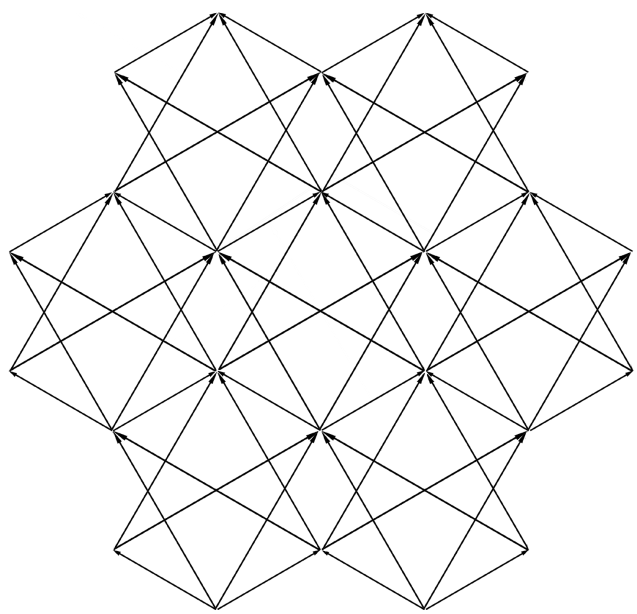
The top-center diagram I call "the primitive diamond." It can accommodate one or two additional arrows without any increase in the number of moments, as depicted in the center column. Looking down the center column of diagrams, each finite sequence is a distinct chronological structure as defined by isomorphism; the *absence* of a pairing connection between two particular moments is no less important in denoting structure than the *presence* of a pairing connection.

Any closed diagram, including the ones shown above, can serve as a basic repeating "cycle" for constructing further closed diagrams, by defining the latest moment of one cycle to be the earliest moment of another such cycle. This is called "chained repetition." For instance, the primitive diamond can propagate indefinitely in chained repetition. Such a propagating sequence of characteristic cycle-structure will replace the notion of "a particle persisting through time." The particle-like sequence will have its characteristic DeBroglie wavelength and frequency. It turns out that the most prevalent stable particles in physics are modeled by chained repetition of the simplest, most symmetrical time patterns. The primitive diamond and its variations must model something very basic, such as polarized light, but I haven't studied it.

We shall skip past the diagrams that have exactly five moments, in order to focus on the following arrangement of six moments, connected by 10 arrows, which I call "the hex cycle."



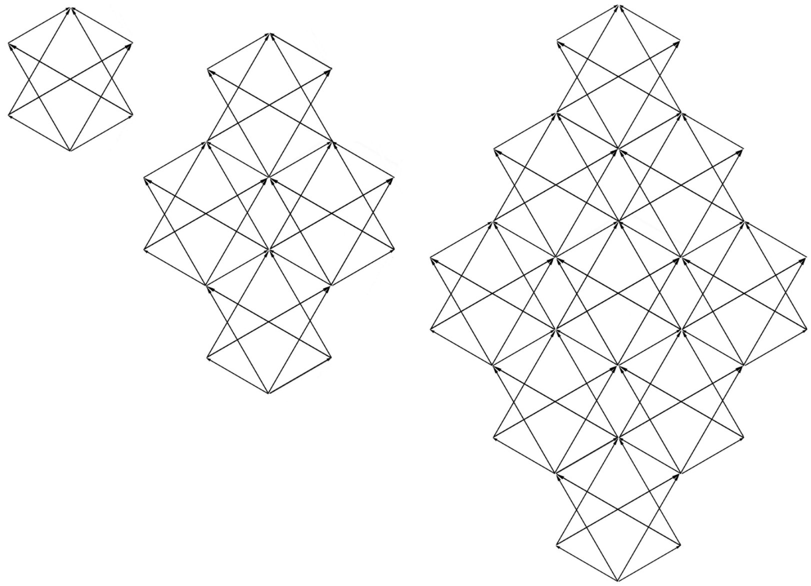
The hex cycle diagram is closed and highly symmetrical. In chained repetition, it will model a neutrino. Equally important, the hex cycle serves as the basic "cell" to compound the cell-like structure of four-dimensional time. I've drawn the hex cycle on the points of a regular hexagon so that it can be tiled graphically with others like itself to make an extendable 4-D time lattice.



In the above diagram, six hex cycles are ringed around a center one. Additional outer rings can be outfitted to extend the tiling pattern uniformly in all directions without limit. In the absence of a continuum, *dimensionality* is a matter of counting the arrows that meet at each node of a regular pattern. Notice that every interior node is at the intersection of four time axes, with four arrows arriving and four departing. This structural plan for an extendable 4-D manifold will serve to replace "space-time."

The "Honeycomb Series" of Closed Diagrams

We can also define a series of diagrams of increasing extent by compounding hex cycles in the following manner, which produces only closed diagrams.

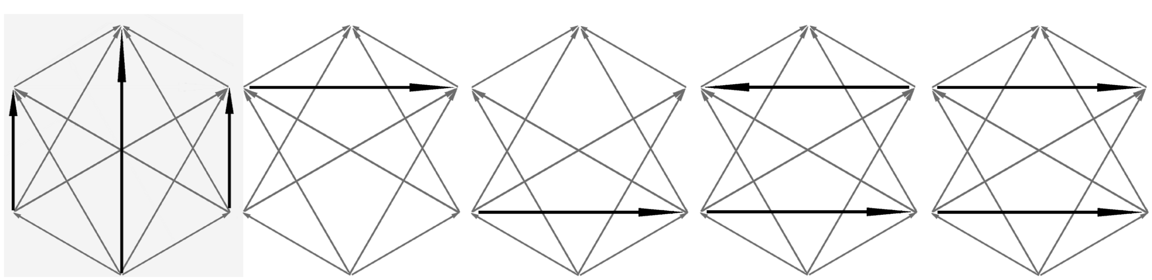


In the above series, as in the previous tiled diagram, every interior node is at the intersection of four time axes. Every quantum belongs to one of the four time axes. We shall call these quanta "lattice quanta," because they form a localized portion of 4-D time lattice. Choosing a sufficiently large "n" as the n^{th} member of the above series, we can obtain a bounded region of 4-dimensionality suited to span a cosmic scale. Such a 4-D manifold, like anything in this theory, is made of quanta. The *4-D volume* of any subregion is measured by the number of component hex cycles.

We are reformulating Special Relativity to employ four time axes all alike, rather than three of space and one of time. All coordinates are then real-valued, and we dispense with imaginary numbers. Also, there is no need to invoke an axiom for the limiting velocity of light. That limit is a logical consequence of excluding instantaneous spatial relations from the theory. A spatial relation is, in effect, *a simultaneity relation*. The exclusion of primitive spatial relations from physics is the simplest way to implement Special Relativity and its "breakdown of simultaneity,".

Quanta of momentum and charge

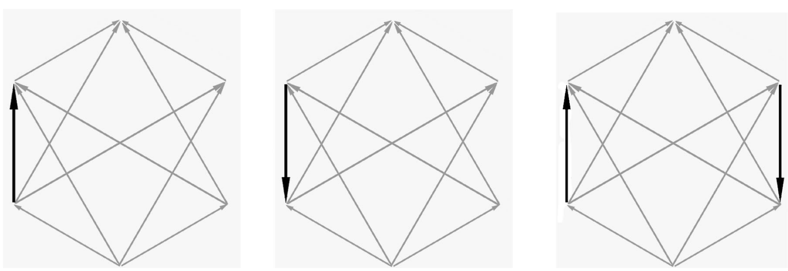
It is *charge quanta* that distinguish electrons from neutrinos. See the following figure, which shows the additional quanta locations afforded by the hex cycle.



Placing the greatest importance on the hex cycle as the basis of our four-dimensionality, I have preserved its integrity as the template of all five diagrams. Variations are obtained by selective inclusion of the additional quantum possibilities afforded by the six moments of the hex cycle. In the leftmost diagram, I have drawn *quanta of forward momentum*. That hex cycle has a major axis quantum—the center arrow—which transitions directly from the earliest to the latest moment of the cycle. Such a quantum has the greatest duration and the least energy of any quantum in its cycle. It occupies the axis of bi-lateral symmetry inherent in the hex cycle. I have also drawn both of the other "vertical" quantum possibilities, thereby preserving the bi-lateral symmetry. The "parallelism" of those three quanta is a topological feature of the hex cycle, and not just an artifact of the geometry of regular hexagons that I've employed in my drawings. The major axis and its parallels define the *axis of proper time* intrinsic to the hex cycle.

The other four diagrams include either or both of the *charge quanta* possibilities. The presence of any charge quantum breaks the bi-lateral symmetry about the major axis of the cycle. Flipping or rotating an entire diagram does not affect its structure, so the four diagrams above exhaust the charge possibilities of a single hex cycle. If we were to include all three verticals plus two horizontals (two charge quanta) in one hex cycle diagram, the diagram would be *full*. More moments would be needed to accommodate more quanta within the region of such a cycle. The limited capacity of the hex cycle for additional quanta serves the same function as the Pauli exclusion principle.

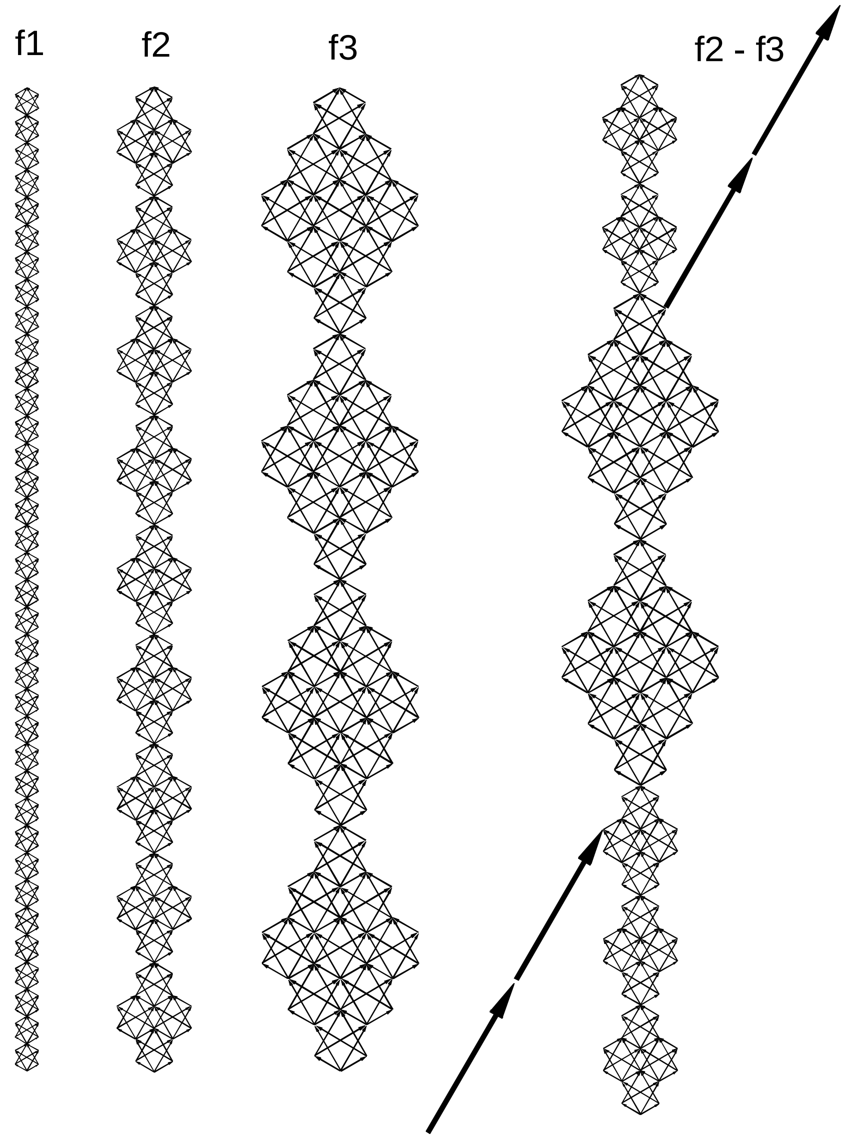
Symmetries of the hex cycle correspond to the symmetry rules governing charge-conjugation, parity, and time reversal. For example, a hex cycle of 10 arrows has mirror symmetry about its major axis (parity.) Also, if we reverse the direction of every arrow in a hex cycle diagram, we end up with the same diagram we started with (time reversal.) There are three further arrangements for quanta in the proper time axis of the hex cycle that serve to explain the *spin* parameter of QM:



The vertically aligned arrows are in the proper time axis, whether they point up or down in these hex cycle diagrams. Chronology protection precludes two down-arrows in a single hex cycle, because a 4-step closed loop would be formed. Only one down-arrow can be accommodated. A down-arrow constrains the orientation of charge quanta that can accompany it. For instance, the hex cycle on the right can accommodate up to two charge quanta, but given the orientation of the up/down arrows in that cycle, the left-right direction of each charge quantum is dictated by chronology protection. Thus, there is a type of "handedness" to a hex cycle that includes "down-arrows."

Bohr's Formula

The *chained repetition* of any one diagram in the "honeycomb series" depicts a mode of *neutrino* propagation. Electrons and their cloud formations have the same structure as the neutrino formations, except that electron clouds are occupied by charge quanta, while neutrino formations consist entirely of lattice quanta. The chained repetition of a single arrow models the *photon* of radiant energy. The justification for these claims is given in the next illustration, which models Bohr's formula for the "spectral fingerprints" of the atoms.



I have drawn the hex cycles as neutrino cycles, without any charge quanta. As drawn, they depict modes of neutrino propagation. If we populate the hex cycles with charge quanta, we get electron clouds. In that case, we would have, from left to right, a *free electron*, a *hydrogen cloud*, a *helium cloud*, and finally, a hydrogen cloud sequence disturbed by an encounter with a photon. The first three diagrams mark the start of a progression that continues in step with the periodic table. The stable clouds feature uniform cycles of uniform frequency. The cloud disturbed by the photon exhibits a modulation of cycle-pattern and frequency. The frequency of the photon, either incident or emitted, is the difference in frequency of the two cycles involved in the modulation. This scenario, generalized to the whole series of cloud possibilities, yields Bohr's formula for the spectral wavelengths of photons absorbed and emitted by the atoms.

Counting the hex cycles of a sequence gives a rough measure of the total energy of that sequence. Each sequence is scaled so that 36 hex cycles span the height of the diagram. Thus the same amount of energy plays out in the same amount of time for any of the cloud formations. That conjugate relation between time and energy holds quite generally, even when the nuclear energies are taken into account.

The spectral line wavelengths are generated by Bohr's formula, $R(1/k^2 – 1/n^2)$. "R" is the Rydberg constant. We adopt the electron cycle—a topological construct—as the unit of energy. The same electron cycle also provides a natural unit for duration and frequency. We postulate that *n* electron cycles establish the same time interval regardless of the cloud structure, as implemented by the progressive scaling employed in the series of diagrams. The wavelength of a free electron is 1 and its frequency is 1; the wavelength of hydrogen is 4 and its frequency 1/4; the wavelength of helium is 9 and its frequency 1/9, and so on. Thus, the frequency of the photon depicted in the diagram (the inverse of its wavelength) is 1/4 – 1/9, satisfying Bohr's formula and my own equivalent formula, f2 – f3.

Bohr's formula encapsulates a wealth of spectroscopy data. An explanatory model of the underlying structure of electrons and their behavior should not be more complex than the empirical data it is supposed to explain. The model represents *theory*, while the tidy formula represents the data which the theory is concocted to explain. In contrast to Bohr's model, we now have a model of electron-photon dynamics that is nearly as simple as the formula which encapsulates the data. It is a model consisting of quantum schematics that can be diagrammed precisely. With this model, the Rydberg constant resolves to unity, because the electron cycle provides the unit of mass and the unit of charge, while the constants "*c*" and "*h*" resolve to unity by more general considerations. We're left with the diagrams themselves, in which the electron appears as the "realtime clock" that sets the base frequency for the EM spectrum.

Time Dilation in the foregoing illustration

On this theory, the "slowdown of time" is the *origin* of gravity, rather than a side-effect of General Relativity. Progressive scaling has been applied to each successive cloud formation in the atomic series. Admittedly, this was done *in order to model Bohr's formula*. The energy inherent in a closed-diagram sequence is evidently tied to the metric of time steps in that sequence, so that the two are co-determined. The *cumulative* effect, of hex-cycle expansion with larger cloud formations, is the systematic deformation of the 4-D manifold according to local mass density. This constitutes a discrete version of General Relativity's "curvature of space-time."

The inverse square laws, for both gravity and EM, are directly related to the inverse squares of Bohr's formula. The reason is this: the 4-D manifold that's been called "space-time" is nothing else than the aggregate of all neutrino/electron formations. We have seen that neutrinos and electrons are formed with the structural principle of an extendable 4-D time lattice. All such sequences connect to one another at some point in their past and at some point in their future, because the theory is built up entirely from causally closed regions. (That confines theoretical constructions to the scope of the scientific method, since the closed-region experiment is the only means of subjecting theory to empirical confirmation.) The connected "skein" of neutrino/electron formations in a closed region accounts for the four-dimensionality of Special Relativity, without invoking any additional homogeneous background. The gaps that break up the uniformity of the manifold delineate the neutrino/electron formations that comprise what there is of that manifold.

Since Bohr's formula characterizes the metric of the "neutrino foam," it characterizes the underlying metric of space-time itself. That is why the inverse squares in Bohr's formula dictate the inverse square laws that govern separation/approach dynamics.

One expects linear incrementing from an independent time axis. But proper time is not an independent axis—it is a resultant axis of 4-D propagation. The hex cycles establish a proper time axis in conjunction with four axes of lattice quanta. We measure time along such a proper time axis, which increments as an integral component of our local 4-D lattice propagation, such that cycles of equal energy transpire in equal time periods. If we fail to take into account the disparate proper-time metrics of locally-isolated inertial systems, we attribute the mutual approach or separation of such systems to the deflecting work of forces that obey an inverse square law.

The Fine Structure Constant

Returning to the "honeycomb series" of cloud cycle formations, let us use **N** to index the members of that series, so that **N**=1 for the cycle of a free electron, **N**=2 for the hydrogen cloud cycle, **N**=3 for the helium cloud cycle, etc. The following formulas then apply to cloud-cycle **N**:

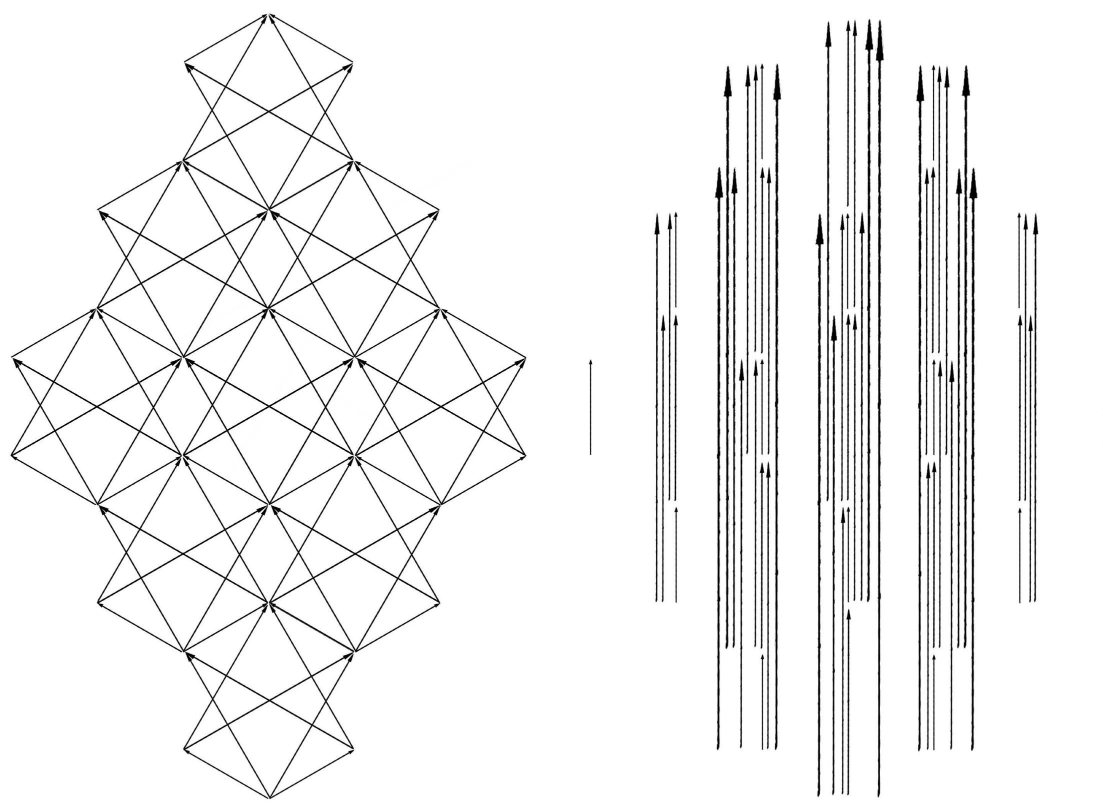
The number of hex cycles is $\mathbf{N}^2$.

The number of lattice quanta is $8\mathbf{N}^2 + 2\mathbf{N}$.

Defining "$\mathbf{S}_{(\mathbf{N})}$" as the *sum of squares* from 1 to N, the number of locations for quanta in the proper time axis is $4\mathbf{S}_{(\mathbf{N})} + \mathbf{N}^2 - 2\mathbf{N}$.

Testing out the latest formula, for **N**=1, we get 4 x (1) + 1 – 2 = 3, which is correct for the single hex cycle. For **N**=2, we get 4 x (1+4) + 4 – 4 = 20, which is correct for the hydrogen cloud cycle. For **N**=3, we get 4 x (1+4+9) + (3 x 3) - (2 x 3) = 59, which is correct for the helium cloud cycle.

Using the above formulas, for any given cloud cycle **N,** we can add the number of lattice quanta to the number of proper time locations. For **N**=3, we get 78 + 59 = 137. The next drawing shows a helium cloud cycle with the two components separated out. The proper time quanta are displaced to the right for ease of discrimination.



I suggest that the above causal set diagram provides the interpretation for the FSC. The "hexagon tiling scheme" is just barely established in the case of **N**=3. Honeycombs of higher index than **N**=3 consist of either a hydrogen cycle (**N** is even) or a helium cycle (**N** is odd) enclosed by concentric rings of hex cells. Thus the cycle diagrammed above is a very basic substructure of any more extensive 4-D latticework, providing a basis for the calculation of charge quanta occupancy arrangements in space-time—quantum electrodynamics.

As **N** becomes large, the number of proper-time quanta locations approaches $(4/3)N^3$. The limiting *density*, of quanta-count per unit volume, is obtained by dividing $(4/3)N^3$ by the 4-D volume of the region in hex cycles, N^2. So the capacity limit of the honeycomb series, for proper-time quanta per unit volume, approaches (4/3)N. This may have application in cosmology. The mass-energy calculation, for a given region of space-time that is mostly vacant of atomic nuclei, concerns the 4-D lattice quanta together with a complement of proper-time quanta. Here we have a basis for calculating the mass of "empty space," which should explain the "dark energy" discrepancy in cosmological accounting.

Quantum Mechanics

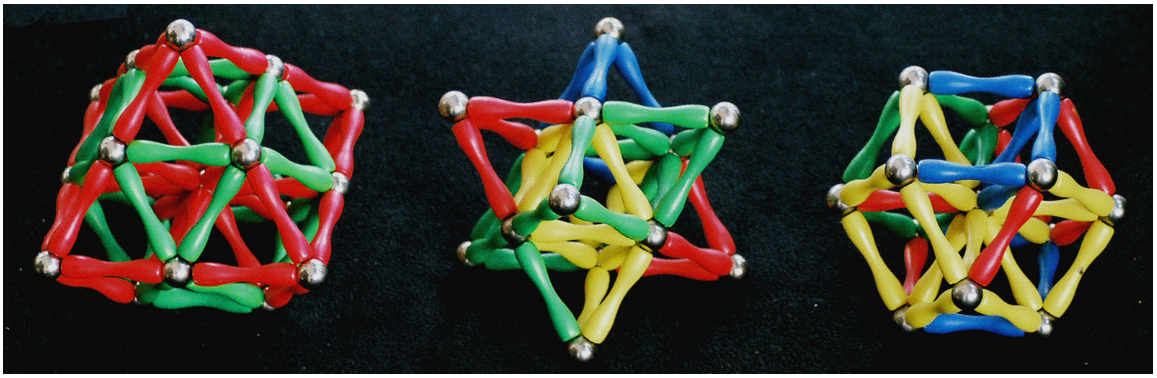
Quantum mechanics employs a 4-tuple of integer values to specify the "electron state" of an atom. The 4 integer parameters are associated with four concepts tied to Newtonian physics: orbit number (Bohr orbit,) sub-orbit number, angular momentum, and up/down spin. If we set out to populate our cloud formations with quanta of charge and momentum, we foresee a limited range of available "fill patterns." A lone hex cycle offers two "slots" for charge quanta, and three more slots for quanta of forward momentum, as shown previously. The number of fill patterns grows systematically with increasing cloud size. The concentric rings of hex cycles, on this theory of cloud structure, provide the orbit and sub-orbit numbers for the 4-tupled values of QM. The values associated with angular momentum must indicate alternate fill patterns that can align in off-axis orientations to the proper time axis. The up/down spin parameter doubles the number of "electron states" that are due to the first three parameters. Looking back at the explanation for *spin* that was proposed earlier, it seems that the spin orientation of any one hex cycle in a cloud must match the spin value of all hex cycles in that same cloud, yielding only two alternatives for each possible cloud-seeding arrangement that would otherwise obtain without taking spin into account. This would explain the doubling effect of the spin parameter on the total number of possible cloud-fill patterns.

I have put the term "electron state" in quotation marks because there is no such thing as a *state* in this theory. Sheer temporal succession is purely dynamic, providing no such thing as an instantaneous state. A quantum is certainly not a *state*. The only static entity is the generic individual moment, which has no variability or numeric value; thus the "state" of a moment has no utility in physics. Instead of *states*, there are distinct arrangements of quanta that characterize the variety of pathways from the earliest moment to the latest moment of any bounded region of time. A given cloud cycle is such a bounded region of time, and the 4-tupled values of QM characterize the possible arrangements of quanta in that cloud cycle.

Nuclear Structure—the 6-D Time Lattice

Attached to periodic nodes of an electron cloud sequence is a nuclear sequence comprised of higher frequency quanta. This constitutes a synchronization of the nucleus to its electron cloud, and assigns the nucleus its location in the 4-D manifold. The "attachment" of nucleus-to-cloud can only mean that the two discriminable sequences share periodic nodes. In general, "attachment," "connection," "contact" or "collision" between discriminable propagation sequences can only mean that such sequences develop *shared nodes in common*.

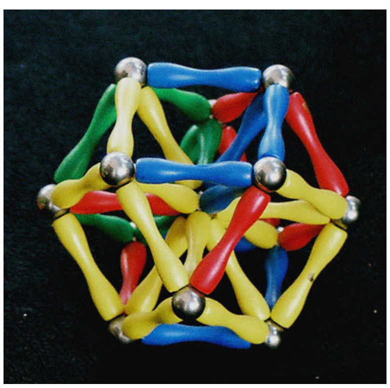
The following photograph of three ball-and-stick models illustrates the construction principle of the *nuclear time lattice*. This lattice will supplant the concept of a nucleus composed of quarks and gluons. The magnetic struts cling to the steel ball-bearings. All struts are the same length. The color of a strut has no significance.



The three assemblies shown are substructures of a single lattice. The assembly in the middle can be described as a unit octahedron with a tetrahedron erected on each face. On the right we see a cuboctahedron, with 6 square faces and 8 triangle faces. "Caged inside the cuboctahedron" is a center ball-bearing with 12 radial struts connecting to the 12 outer vertices. If we erect a pyramid on each square face of the cuboctahedron, we get an octahedron of edge length 2, as shown on the left. (Its bottom pyramid is omitted in order to allow the assembly to stand upright.) The principle of the lattice is this: each unit tetrahedron shares its faces with octahedra, and vice versa; no tetrahedron or octahedron shares a face with one of its own kind. Following this rule, we can fill space with a mix of unit tetrahedra and unit octahedra. As we fill space, the above forms will recur periodically in the lattice. Larger versions will also be formed, at twice the size, three times the size, etc. This lattice principle has widespread practical use in building design, for which Buckminster Fuller named it "the octet truss."

The spatial lattice exemplified by the models becomes a *time lattice* when each strut is assigned an unambiguous direction (while obeying chronology protection.) Each strut is then a quantum. We thereby obtain a richer structure—a causal set—composed entirely of time-directed pathways.

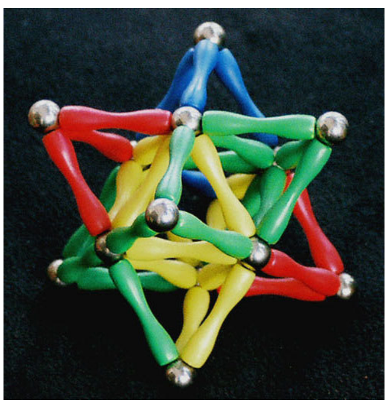
We are exploiting well known regular solids of high symmetry in order to obtain causal sets that exhibit comparably high symmetry. When converting a finite spatial topology to a causal set, the directionality can be assigned in such a way as to maximize the preservation of symmetry. The "time tracing" can yield a causal set with symmetry that rivals the topology of the regular solid being traced. In tracing the above models in order to arrive at causal sets, there are four axes of orientation that yield high symmetries. We can specify each of these axes by reference to the cuboctahedron model:



One axis runs from the *center of a triangle face* to the center of the diametrically opposed triangle face. This results in 3-way symmetries about a proper time axis. An alternate axis runs from the *center of a square* face to the center of the opposing square face, resulting in 4-way symmetries about that time axis. A third axis runs from any *vertex* of the cuboctahedron to the diametrically opposed vertex. Finally, an axis of high symmetry runs from the *center of any edge* of the cuboctahedron to the edge-center that is diametrically opposite.

The cuboctahedron model has one interior node joining 12 struts. These 12 struts become 12 causal links, once we've performed a time tracing. There will be 6 quanta arriving and 6 departing at the interior node. As the lattice is extended, every interior point will have that same context. The nuclear lattice structure is thus a "6-D time lattice." We now have the terms "4-D lattice" and "6-D lattice" to distinguish EM structure from nuclear structure. The 4-D lattice is the more extensive of the two, since it is space-time. The 6-D lattice only extends far enough to form highly symmetrical structures that can propagate on their own by chained repetition. These nucleons of characteristic 6-D structure have their location in the more extensive 4-D lattice by sharing periodic nodes with their companion electron clouds.

Structure of the proton



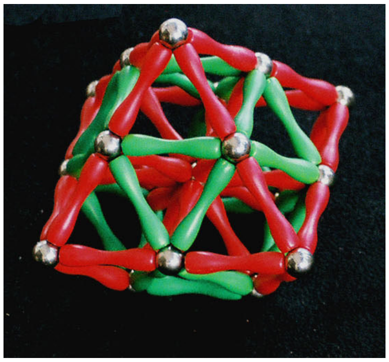
The proton has the overall structure of a cube, for which the model pictured above can be referenced. The eight outermost ball bearings define a 3-D cube that envelops the discrete structure. The model shows the minimal cube that can be formed using the 6-D lattice principle. It's actually an 8-pointed star, but I'll call it a "small cube." The model is resting on one of its sides, but the camera angle almost provides a line-of-sight through the small cube from one corner to the opposite corner. This is the time-tracing axis by which the spatial topology is converted to the causal set structure of a proton. Such a tracing yields 3-way symmetries among the constituent quanta, about the axis of proper time. Quanta which break the 3-way symmetry are *color-charge quanta*. To form a stable proton, the color-charge quanta must form 3-way symmetries amongst themselves in a suitable arrangement.

A larger cube can be constructed by assembling 8 small cubes together in a 2x2x2 arrangement. The next larger cube after that is 27 small cubes in a 3x3x3 assembly. Here I believe we have arrived at the structure of a single proton. The small cube has 36 struts. Thus the 3x3x3 assembly has roughly (27 x 36) struts. 1836 is (27 x 34) x 2, which is the empirical mass-ratio of proton-to-electron. The approximation of (27 x 36) to (27 x 34) is a clue that the 3x3x3 assemblage of small cubes will yield the causal set structure of a single proton cycle.

Inspecting the small cube model along the line-of-sight, just below the nearest vertex, one sees a triangle, of 3 yellow struts, that is perpendicular to the time-tracing axis.

There is a second such triangle further along that axis, diametrically opposed. These two triangles contribute to the 3-way symmetries of the spatial form. As *time triangles*, however, they present a symmetry problem. Three radial directions are possible for one of the triangles, and three more for the other triangle, for a total of six distinct radial directions. Six of these "axis-hugging" triangles are needed to achieve a radial symmetry in the proton cycle. A 3x3x3 assembly of small cube cycles has three small cubes stacked up in chained repetition along the major time axis. Those three cycles contain two problematic triangles apiece, for a total of six. Thus the six triangles can assume the six different radial directions, salvaging radial symmetry for the overall proton cycle.

Structure of the neutron



If we view this model from directly above, we see nothing but 4-way symmetries, which suggests a *neutral* orientation with respect to the 4-D electron-neutrino lattice. The octahedron has 8 faces and 6 vertices, while the cube has 6 faces and 8 vertices. The two Platonic Solids are called "duals" for that reason. When constructing models on the 6-D lattice principle, the cube and the octahedron serve to compound one another in various ways. This will account for the role of protons and neutrons as major substructures of the nucleus. At this stage of development, one must conclude that the simplest, most symmetrical topologies correspond to the most primordial substructures of matter. Both the proton and neutron have their quanta in the 6-D lattice arrangement. A proton has the overall topology of a cube. A neutron has the overall topology of an octahedron. The above model is an octahedron of edge length 2. A larger version of the octahedron, of edge length 6, will yield a model of the neutron, as counterpart to the 3-cube model of the proton.

Mass values of proton and neutron

The calculation of energy ratios is not trivial in general. Each quantum must be weighted by its relative frequency, which involves the whole network of its neighborhood within some specified bounded region. However, in the case of a regular lattice, if the lattice quanta are of uniform frequency, energy calculations can be as simple as counting quanta. The first step in calculating the mass-energy of the proton is to count the lattice quanta in the 3x3x3 assembly of small cubes that makes up a proton cycle.

My formula for number-of-struts in an NxNxN assembly of small cubes is:
N-cube struts = $\mathbf{24N^3 + 12N^2}$.

By the formula, the 1-cube model (the "small cube") calculates to 36 struts, which is correct. The 2-cube has 240 struts, and the 3-cube has **756** lattice struts.

The 3-cube lattice assembly provides locations for additional quanta at stepped-down frequency values, just as the 4-D lattice provides locations for its own lower frequency quanta. For instance, each "X" on the face of a small cube is made up of 4 struts. A half-frequency strut (twice the length) can span each small-face diagonal also, adding 108 struts, at half-frequency, to the 3-cube. This would add 54 to the 756 energy calculation.

My formula for the number of lattice struts in the octahedron of edge length "N" is: Octa-N struts = $\mathbf{12 \times S_{(N)}}$. ($S_{(N)}$ is the sum of squares from 1 to N.)

The unit octahedron (N=1) calculates to 12. The Octa-2 (the model pictured) calculates to 60 struts. The Octa-3 has 168 struts. The Octa-6 has **1092** struts. The Octa-6, with an edge-length of 6 struts, is the finite structure proposed for a neutron.

As oriented in the photo, an octahedron has a number of "horizontal floors" that consist of square tiling arrays. The time-tracing of these horizontal struts presents symmetry problems, so some of those struts might be excluded from the neutron, reducing the count from 1092. The "odd numbered floors" are particularly difficult to time-trace with any great symmetry. These are the floors with 1, 9, and 25 tiled squares. By omitting these floor struts, we reduce the Octa-6 strut count by 176, to **916**.

To summarize, we have the 3-cube for a proton and the Octa-6 for a neutron. Each face of the 3-cube has *diagonals* that are 6 struts in length, while the Octa-6 has an *edge-length* of 6 struts. The 3-cube has 3 small cubes, in chained repetition, forming its core along the major axis. The Octa-6 has 6 unit octahedra in chained repetition that form its core. Lattice-count for the two assemblies is 756 and 1092, respectively. The sum of those two numbers is 1848, and the average is 924. The lattice-count of the 3-cube is 168 short of the average, and the lattice count of the Octa-6 is 168 high of the average. (168 happens to be the strut count of an Octa-3.) We have lowered the neutron mass close to the 924 average, by deleting some floor struts. We've added weight (+54) to the proton model by including some half-frequency quanta. Another 108, or 27 x 4, is needed to bring the proton mass up to **918** (half of 1836.) We have not yet considered any locations in the 3-cube, or any locations in the Octa-6, for quanta in the proper time axis. I will assume, at this point, that further detailed considerations can bring the modeling of the proton cycle and the neutron cycle to their empirical mass values, or rather, to their *half-values*. Next we consider the compounding of protons and neutrons to make larger nuclei, and the relation of a nucleus to its electron cloud.

The integration of nucleus and electron cloud

A beautiful thing about the cuboctahedron is that its edges are formed of 4 regular hexagons, which encircle the solid like great-circle routes. In fact, the octet truss can be assembled entirely from regular hexagons. The hex-cycles of the 4-D lattice are also hexagonal in their topology.

We have already taken some account of lower frequency quanta (lower frequency than the lattice struts) that can populate regions of either lattice type. Now consider the Octa-6 formation. It has the overall contour of a single octahedron with 6 vertices. These 6 vertices are connectible by 12 quanta to form a low-frequency octahedron that borders the whole assembly. A ladder of discrete nuclear frequencies extends from the high-frequency value of the 6-D lattice struts to the lowest frequency quanta of the "envelope octahedron" just described. At this point, the lowest nuclear frequencies match up to the frequencies of the hex cycles of the 4-D lattice.

The 4 hexagons that encircle a cuboctahedron are also present on the surface of an octahedron or a cube. The 4 hex cycles of a hydrogen cloud might therefore be situated "on the surface" of a proton, having assumed the identity of the low-frequency cuboctahedron that the proton structure accommodates. The nuclei of atoms in the Periodic Table might variously exhibit the overall form of a cube, an octahedron, a cuboctahedron, or compounds and stellations of those forms. Whatever form the larger nuclei might take, they will afford low frequency hexagon locations to accommodate the low frequencies of time-dilated hex cycles.

Since the hexagons of the 6-D lattice assume four distinct orientations, only one of the four orientations can mesh with the 4-D lattice. Only one orientation of a nucleus can be brought into line with the proper time axis of the local 4-D manifold. A given form of nucleus will have one of its low-frequency hexagons properly oriented to mesh with the neighboring hex cycles of its electron cloud, fitting the nucleus into a honeycomb cycle.

In this paper, rudimentary forms have been used to model the non-perturbative persistence of stable particles. Collision and interaction of particles involves transitional forms with short persistence. These intermediaries are presumably deficient in respect to their inherent symmetries. The detailed topology of perturbative sequences is a task well-suited to experts in the field of regular polygons, and more generally, the field of regular polytopes. These lend themselves readily to conversion to causal sets, at which point energy calculations can be brought to bear.

Summary

This theory offers a solution as to what particles are, what mass is, and why particles have the masses they do. Particles are repetitious patterns of time sequence, and the mass-energy of a particle is the measure of its inherent relative frequencies, which is a function of the number and arrangement of its constituent quanta. A particle sequence as a whole must in turn have a frequency relative to other particles, since all frequency is relative. All quanta of this universe connect into one structure. That is what “this universe” means. The causal connectivity is what rationates the frequencies, or energies, of this universe.

I came to these constructions via Russell and Whitehead’s doctrine of space-time called “eventism.” They had developed the event ontology in response to Special Relativity. The ontology they embraced is one of momentary monads, akin to Leibniz’ monads. The epistemology and phenomenology that underlies causal set theory was all worked out by Russell in *Human Knowledge: Its Scope and Limits*. The phenomenology of mind—as for example, the sensuous visual field—is a domain of true spatial relations and geometry. However, the subject matter of physics is a world *external* to our perception, purely sequential in nature, and devoid of instantaneous spatial relations.

As an isolated researcher, I refer to my own publications for further background on the reduction to time. The diagrams, and the recognition of frequency ratios as energy ratios, first appear in *The Mind-Body Problem and Its Solution*, 2004. Subsequent development of the diagrams, to the point of Bohr’s formula, appear in *A Theory of Everything for Physics*, 2005. An article, “Finite eventism,” appears in the book collection *Mind that Abides: panpsychism in the new millennium*, 2009, Benjamins Publishing. The article covers much the same ground as this paper, but adds a section on the functional role of the cortical homunculi, under the assumption that the brain is a causal set.