Discrete Theoretical Processes

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One open question in the field of Theoretical Physics has to do with the most microscopic of phenomena. We herein will examine consequences of assuming that space, time, state and all other properties and processes of physics are finite, discrete and deterministic. We already know that microscopic matter consists of discrete particles and that microscopic forces are mediated by discrete particles. If our assumptions were true then a comprehensive theory of discrete physics ought to contain non-tautological explanations for what we call "Small integer phenomena": the constants of physics that are characterized by small integers. Some examples are:

1 - photon
2 - directions of time
2 - particle and antiparticle
2 - signs of electric charge: ±
2 - flavors per generation
2 - fermions per generation (e.g. electron, quarks and lightest neutrino)
2 - spin states of electron and other $\hbar/2$ particles: Up or Down
2 - spin states (boson – fermion: even or odd multiples of $\hbar/2$)
3 - spatial dimensions
3 - generations of flavors (e.g. electron, muon and tau)
3 - generations of Quarks
3 - colors of Quarks
3 - massive bosons, W^+, W^- and Z^0
3 - kinds of particles with integer multiples of ±1/3 charge. Etc.

In addition, we ought to be able to find, over time, relatively simple derivations for all of the constants of the Standard Model. Most importantly, if space, time and state are discrete and if some kind of DTP could model the most microscopic processes in physics exactly, then, depending on the scale of quantized space and time, we might be able to finally understand every aspect of microscopic physics including Quantum Mechanics. Those are some of the attractive possibilities.

Unfortunately, if our assumptions are true there are also many unattractive consequences. Almost all of the wonderful analytic formulae in all of physics would be relegated to being no more than good approximations of the actual discrete measures of space, time, energy, momentum, etc. All of the continuous symmetries would also be no more than good approximations. On the other hand, it is quite possible that various conservation laws could, nevertheless, still be true and exact even while being discrete.

We are attempting to maintain clarity, in in this document, by indicating our use of words that have somewhat specialized meanings by presenting them (and no others) in italics. When context seems to be an insufficient guide, we will provide definitions.

DTP is not conceived of as a system where, at an instant in time, the known physical particles are located at discrete points in space. Rather, we imagine that the occupant of every point in space is a simple *token* (perhaps similar to a 3 state version of a bit in a computer; sometimes called "trit". Stable 3+1 dimensional extended *configurations* of *tokens* are what stable particles are made of while unstable particles are similar *configurations* that happen to decay when their ever changing internal state and the ever changing bordering pseudo-random external state satisfy some particular criteria in some way: thus yielding a deterministic half-life decay process consistent with observations (something once thought to not be possible for a simple deterministic process). An example of a deterministic model of half-life phenomena can be seen in: "Circular Motion of Strings in Cellular Automata" by Miller and Fredkin, arxiv. Our task has been and still continues to be: finding ways to explain how various versions of DTP might be able to model more properties of both matter and energy in ways consistent with the known facts; the observations and measurements from experimental physics. We are certain that the kinds of models we are proposing can never be exactly consistent with our analytic laws of Quantum Mechanics, but we shall be content if instead, they are exactly consistent with the microscopic evolution of physical state that we call "Quantum Mechanics".

In the past we have used names such as "Digital Mechanics", "Digital Physics", the "Salt Model" and others as we continued to make modest progress. What we are disclosing here is much improved over all earlier versions but is nevertheless still highly speculative and certainly substantially incomplete and still just plain wrong in some respects. Nevertheless, in this paper we explore various aspects of discrete models while solving a number of problems that we didn't know how to solve in the past. Our progress has been slow but steady as we keep finding additional possible models for various additional aspects of physics. Our study of DTP advances despite the current lack of direct experimental evidence of the magnitudes of possible discrete measures of space and time.

What will be described are properties of a class of regular, second order 3+1 dimensional Cellular Automata; based on a modified Cartesian Lattice, where something similar might possibly be a candidate for the most microscopic space-time structure of our world. Our current goal is to define characteristics of some such systems that, at a higher level, could result in a correspondence to the laws of quantum mechanics. Along the way, we want to communicate new insights into how it might be, in a discrete space-time-state world, that all things move with apparent translational symmetry.

If ultimately, space, time and every other measure in physics is discrete and if something similar to DTP should turn out to be an exactly correct model of the most microscopic physics, then given nothing new other than the unit of length, the unit of time, the structures that define the most microscopic representation of state, the transition rule that defines the temporal evolution of the most microscopic state, and some characterization of the initial conditions (the Big Bang) it would be possible, theoretically, to compute all of the constants and facts of microscopic physics. However, from a practical viewpoint, this might only be possible if the unit of length was in the range of a Fermi, 10^{-15} Meters. If the unit of length turned out to be closer to Planck's Length, then computer simulations would likely prove very much less useful.

To better understand the kinds of discrete space-time structures we have in mind, it might be helpful to first read earlier papers that discuss the Salt Model.[1] Both papers describe models and methodologies. Some of these may appear as bizarre, but it is important that the reader keep in mind our purpose. We do not have anything like a complete set of reasonable models for discrete counterparts to conventional physics. Instead, most of this work has involved finding discrete deterministic models for various aspects of physics and counterexamples to the commonly stated proposition that such discrete systems cannot serve as appropriate models of various aspects of microscopic physics. As such, some of our examples may seem bizarre or even ridiculous. No matter, their only purpose is to exist as counterexamples to the claim that such discrete models are not possible.

The best example has to do with translational Symmetry despite having a fixed Cartesian lattice as the substrate for space-time. We have so far found several approaches to defining discrete processes that model Translational Symmetry; some are reasonable; there are others which most readers would find wholly unreasonable. At similar points in the reading of this paper, we seek your indulgence. Keep in mind our purpose – which is more about defining the problems we still must solve in order to understand DTP, as opposed to supplying all of the answers. Our approach, necessitated by our primitive methodologies, has been finding counterexamples to concepts that seemed, at first glance, to rule out DTP as a potentially competent model of physics. For example, it is widely thought that: "A model of space-time that is based on a single fixed Cartesian Lattice cannot support translation or rotation symmetry." We can now demonstrate that that thought is too simplistic.

An interesting new development was finding models of simple QM Harmonic Oscillators that are highly stable despite operating in a CA without the ability to perform any arithmetic operations other than processes where nearby

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[1] *Five Big Questions With Pretty Simple Answers*, Ed Fredkin; *Two-state, Reversible, Universal Cellular Automata In Three Dimensions*, Ed Fredkin and Daniel Miller; *Circular Motion of Strings in Cellular Automata and Other Surprises*, Daniel Miller and Ed Fredkin. On the www.digitalphilosophy.org web site

tokens conditionally permute positions with their neighbors. In other words, the behavior of a trivially simple CA can, amongst other things, model microscopic processes where the corresponding higher level mathematical models involve complex analytic functions.

Finally, we offer an explanation as to how totally discrete models can explain, in general, the wonderful and miraculous applications of mathematical analysis in physics; made even more wonderful if space, time and state are all discrete! Simply put: the success of analysis may be a consequence of trivially simple microscopic processes in discrete space time state systems that happen to exactly conserve discrete quantities such as energy, momentum, angular momentum, charge… and so forth!

2. Understanding DTP

The science of physics and the art of mathematical analysis have co-evolved in an amazingly fruitful manner. Today we represent most of the laws of physics by means of equations where the functions and variables are continuous. However, when we think about DTP, with space, time, state and all other attributes of the most microscopic physical processes being discrete, we find mathematical analysis often inappropriate at the most microscopic level.

Discrete Theoretical Processes (DTP)

Even our current use of natural language is limited in its ability to describe aspects of DTP.

The key concept that allows fundamentally discrete and deterministic microscopic models to be well characterized by mathematical analysis has to do with exact conservation laws. DTP processes are capable of conserving, exactly, various quantities of physics including those involved in processes characterized mathematically by a Hamiltonian or a Lagrangian. In such cases a version of Noether's Theorem can still connect the two properties of conservation laws and corresponding continuous symmetries. Within DTP there is nothing that has the property of continuity, however, at scales above the most microscopic, we can nevertheless attribute a kind of asymptotic continuity to DTP evolution of state. We also know that extraordinarily simple computational models of QM systems can be programmed. Thus DTP is certainly not excluded from the possibility of underlying Quantum Mechanics. We must keep in mind the known fact that discrete computational processes can, to any required accuracy, model any and all analytic functions.

We therefore proceed by introducing concepts, through definitions, that we believe to be consistent with our current understanding of the appropriate attributes of this thing we are calling DTP. We investigate various aspects of

DTP related to the known experimentally determined facts of physical space, time, action, charge, energy, matter and antimatter, etc., the fundamental quantities and properties that are the subject matter of theoretical physics. We try to clarify, but only in the context of DTP, both what *information* is and what is *information*. As a result, the word "*information*" will also require a new definition within the realm of DTP.

Some of the words and expressions we use, that are associated with DTP related expanded definitions, are: *discrete*, *local*, *token, rule, fundamental process, state, meaning, information, entropy, explicit information, implicit information, locality, substrate* and *configuration*.

Discrete Theoretical Processes may need only 3 fundamental numerical constants:

1. A unit of Length, L
2. A unit of Time, T
   (Where 6 micro-time steps, t, equal one time step, T)
3. A unit of Action (or Angular Momentum), B ($B = \hbar/2$)

Today, we are quite certain that the unit of action is $\hbar/2$ but the units of Length, L, and the unit of Time, T, are currently unknown. Further, the exact relationship between c, the speed of light, and the units of Length and of Time, insofar as DTP is concerned, are not currently well enough understood. It is clear, however, that there may be problems with the simple minded assumption that either $L/T = c$ or $L/t = c$. In any case L and T must allow for particles whose gross motion is asymptotically isotropic with velocities are always less than or equal to the speed of light.

DTP assumes that all *information* must have a *discrete* means of its representation, called a "*configuration*". All changes of *state* must be consequences of *discrete* informational processes, similar, in some ways, to what occurs within a computer. All processes involve the discrete temporal evolution of a *configuration*, such as its translational motion or the interactions of *configurations* such as an electron interacting with a photon.

A *configuration* is normally a 2^{nd} order in time, spatially distributed collection of *states* that can be interpreted by some *process* in a meaningful way. This always involves, in addition, such properties as the microscopically discrete translational motion of the *configuration* that is associated with a particle. A more complete definition of "*configuration*" will be given later.

In biology, long ago, the observation that for every species, an offspring was always of the same species, was summarized by the saying "Like begets like." The discovery of DNA allowed us to understand that discrete informational representations allowed for a mechanistic explanation of "Like begets like." However, even today in 2011, we still lack a full understanding of all of the processes that enables DNA to control the development of a living thing.

In physics we may have a similar situation with regard to Translation Symmetry and Newton's First Law[1]. While it is doubtful that anyone ever described it as "Velocity begets velocity", within DTP it is clear that the velocity of a particle must also have a *local discrete* means of its representation as some kind of informational *configuration*. In fact, the primary law of all DTP systems is: All *local* state *information*, which includes absolute velocity, must always be represented by a *discrete, local configuration*.

"Discrete" A property of a finite closed system where every one of the *N* distinct different possible states of that system could have an informational, one to one, correspondence with *N* distinct integers.

Discrete Theoretical Processes (DTP)

"Local" *Information* that purposefully affects the evolution of *state* of a particle can be described as *"local"* with respect to that particle. For example, the wave structure that contains directional information with regard to a particular photon, can be described as *local* despite being Meters away from the photon in the plane perpendicular to the motion of the photon.

"Token" is a thing that has one permanent *state* out of a small integer number of possible *states*. For Example, imagine that there are 5 kinds of *tokens* whose names are: $+1$, $+i$, 0, $-i$, -1. Every cell within the Real *Substrate* is occupied by exactly one of the following three *tokens*: $+1$, 0, -1. Every cell of the Imaginary *Substrate* is occupied by exactly one of the following three *tokens*: $+i$, 0, $-i$. We could assume that these 5 types of *tokens* have no properties other than their names. However we expect that our choice of assigning zero and the positive, negative, real and imaginary units as names of the *tokens* will correspond to some of their mathematical properties. *Tokens* are immutable; never changing into different kinds of *tokens*.

"rule" While we do not, at this time, know what the fundamental *rule* is, we can indulge in educated guesses. The fundamental *rule* should be a 2^{nd} order process in order to simplify requirements for the dynamic laws of physics -- such as Newton's laws. It has to, in a sense, produce as a consequence of its operations, evolution of *state* in accord with the known laws of physics. Since our model is a discrete process that will be computation universal, we can hypothesize that any universal system could suffice in that some initial condition is guaranteed to result in some subset of the *states* obeying the laws of physics. This is a weak argument because what we are really looking for is

a universal process that produces the laws of microscopic physics and nothing else. We hypothesize that the Rule could be composed of 6 or more, microscopic sub rules. A neighborhood at t+1 becomes a conditional permutation of that same neighborhood at t-1 as controlled by the *state* of a neighborhood at time t and according to Rule $R_{t\ Mod\ 6}$. As a consequence of the *rule*, small groups of neighboring *tokens* at time t-1, under certain conditions as determined by the *state* of other neighboring *tokens* at time t, will *locally* permute some of their positions while becoming the *state* at time t+1.

All motion and change of *state* must be, most microscopically, consequences of repetitions of such microscopic discrete changes of *state*. There are good reasons to propose a model with 6 differently oriented microscopic steps, each depending on the value of *t Mod* 6, that are similar except for angular orientation. The general idea at this stage has been to focus our efforts by studying rules that should enable higher-level angular isotropy despite the existence of the microscopic Cartesian coordinates. We have so far found fundamental processes that achieve each of our various goals but have not yet found one fundamental process that simultaneously achieves all of our goals.

We assume that the *Fundamental Process* must be exactly reversible, and it must, through its operation, give rise to the fundamental constituents of physics with all of their most microscopic properties. The *Fundamental Process* is a finite discrete deterministic second order system where exactly reversible changes in *state* occur. A guide to discovering competent *Fundamental Processes* will be their ability to reproduce the small integer phenomena described at the beginning of this paper. A possible form of *Fundamental Process* causes all members of a category of *tokens* in S_{t-1}, to conditionally undergo temporal evolution as a deterministic function of neighboring *tokens* in S_t. The temporal evolution results in the modification of the *state* at time S_{t-1} to produce a new *state* which can then be re-labeled as S_{t+1}. It should be noted that since every kind of permutation has an exact inverse and because S_t determines how S_{t-1} evolves into S_{t+1}, all processes, with the properties just enumerated, must always be exactly reversible! Thus we know that DTP can exhibit the same kind of reversibility as is true of microscopic physics. (In order to understand how DTP can exhibit exact CPT reversibility see "Five Big Questions with Pretty Simple Answers")

"Process" This is a tricky concept and it is difficult to understand. In a cellular automaton, there is a rule that governs change of *state*. In Conway's Game of Life, the rule is very simple. Based on a 2 dimensional checker-board like cellular space, every cell has 8 neighbors, 4 nearest neighbors and 4 additional diagonal neighbors. Each cell contains either 1 or 0. "*c*" stands for

the *state* of a cell, "*n*" stands for how many of its 8 neighbors are one and "*C* " stands for the new *state* of the cell, then the definition of the Fundamental Process of the Game of Life is:

If ($n < 2$ OR $n > 3$) then $0 \rightarrow C$; If $n = 2$ then $C \rightarrow C$
If $n = 3$ then $1 \rightarrow C$;

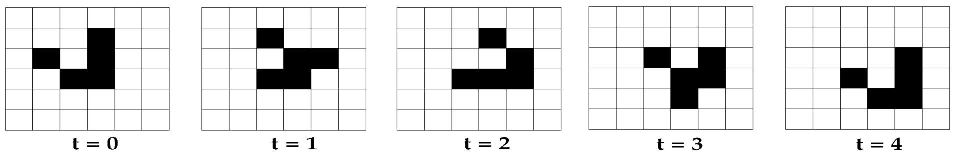

Fig. 1. The temporal evolution of a glider in Conway's Game of Life.

The Game of Life is an example of a very simple 2 dimensional deterministic process that has been proven to be Computation Universal in the Turing sense, however it is obviously irreversible, as many simple *configurations* can simply disappear. Life allows for many different kinds of meta-stable particles that exhibit translational motion at various velocities (such as the Glider) and collisions involving various numbers of Gliders can create new and different particles. The Game of Life illustrates some of the kinds of complexity that can arise in a cellular automaton given a very simple rule but the Game of Life also violates the kinds of conservation laws that exist in physics. Similarly simple cellular automata rules have been found that are reversible, computation universal and subject to conservation laws.

While the Fundamental Process governs all activity in DTP, there are high level processes that create and annihilate various kinds of particles and that result in the motions of the various particles. In DTP these higher level processes are basically interactions between particles and or fields whose existence and properties are all consequences of the operation of the fundamental process. Even in the case of a single free particle, its interaction with its own momentum wave must result in isotropic rectilinear motion. Such processes can underlie the apparent Translational Symmetry of the system; all particles must, of course, be engaged in translational motion. Thus, every configuration has the property of being in translational motion.

"*State*" In the context of DTP – *state* is always represented by a *configuration* where the extent and *meaning* of that *state* is determined by the processes that examine or manipulate those *configurations*.

"*Meaning* " A potential property of some *configuration*, C1, that has *state*. The *meaning* of the *state* of a particular *configuration* is given by a *context* where a discrete process, created by another configuration, C2, examines, interprets, modifies or in any other way – interacts with *configuration* C1. A particular *configuration* can have multiple *meanings* depending on the *context* (depending on which other configuration might interact with it).

"Information" State that has *Meaning*. In this context "*Information*" is a *configuration* that has *meaning*. Thus *meaning* is a property of the combination of a *configuration* and a *process*. Each *meaning* of a *configuration* is given by the *process* that is interacting with it. A given *configuration* can have more than one *meaning*. In an ordinary computer, a process is represented by a block of memory that contains instructions. Data is also represented by a block in the same memory that contains data. The same concept exists in DTP where particles and fields are both patterns in the cellular space that interact with each other. The von Neumann architecture is still the basis of all modern computers; instructions and data share the same memory. It is also our model for DTP. Von Neumann's concept was absolutely prophetic! For example, consider a *configuration* in a contemporary computer that represents a one-minute video. To the process that displays the video, the *meaning* is: "An MPEG file located at address A and of length *N*, to be decoded into a series of raster images which are sent serially to the display driver." To the software that copies the MPEG file to a USB stick the *meaning* is "A binary file, located at address *A* and of length *N*, to be copied to the USB stick". To the software that erases the file the *meaning* is "An arbitrary file located at address *A* and of length *N*, to be erased and the block of memory it occupied is to be given to the Garbage Collector." In each case the process that gives meaning to data is also in a block of words in the same general memory as is the data.

"*Entropy*", in this context, entropy is certainly not the same as *information*. Basically *entropy* is a scalar measure (*Log* of the number of equally probable *states)* associated with *states* that have no individual *meanings* in the context of *entropy*. The *Entropy* of a *configuration* is equal to the number of Shannon Bits needed to specify all of the possible *states* of that *configuration*. *Entropy* does have *meaning,* depending only on the numerical value of the *Log* of the number of individual *states*.

In all cellular automata there is a fundamental process that causes the most microscopic change in *state* as the discrete evolution of *state* proceeds step by step. A "*Configuration*" is a spatial-temporal arrangement of a group of various *tokens* that, as a body, is identified with a particle or a field. However, as a result of the characteristics of different *configurations*, various higher-level processes can take place. Each *meaning* of a *configuration* is given by the higher-level *process* that interprets or modifies the *configuration*. A given *configuration* can have more than one *meaning* as it may be interpreted or modified by more than one higher-level *process*. We assume that, at time t, all of the *tokens* in a *configuration* of *tokens* have time coordinates either t or t-1. A *configuration* is always 2^{nd} order in time. Normally all of the *tokens* in a *configuration* are spatially near to each other. However, in the case of a photon "near" might mean 10 Meters or more. There are 2 aspects of basic *configurations*: those that represent the static characteristics of a particle, matter or field such as the observation that a particular *configuration* represents an electron with its rest mass, charge, spin category (boson or fermion) and those that represent the instantaneous dynamic *state* of that particle; which might include its, spin *state*, momentum and energy, along with any other properties.

All processes, beyond the fundamental process, are consequences of the interactions of *configurations*. A single particle moves as a consequence of interactions involving its momentum wave structure and other aspects of the particle. A field or boson modifies that wave structure.

It is also true that a *configuration* that has *meaning* with respect to one process may be *meaningless* with respect to a second process while having other *meanings* with respect to other processes.

Explicit information is much more common than *implicit information* and, in a sense, is easier to comprehend. The velocity of a particle must be represented by the informational equivalent of an absolute velocity vector. Given one particle as the origin of a coordinate system, the relative motion of a second particle could conceivably be represented by a vector in the inertial frame of the first particle. While this is true, it is unreasonable to assume that velocities of all particles are represented in the reference frames of other particles. We need to imagine how it is that a single particle can have a velocity. We are forced into accepting a very simple solution to this problem but it requires a major philosophical shift. In the discrete space- time-state approach, we find no sensible way to represent the information inherent in the rectilinear motion of isolated particles without conceding to the existence of a single, fixed coordinate system where that coordinate system has many properties in common with a single fixed universal Cartesian Lattice. It is clear that from within a DTP system, all laboratory measurements can be in accord with Special Relativity. Further, all gravitational effects can be in accord with General Relativity. While computational universality guarantees these possibilities they can also be a direct consequence of the rules governing the microscopic evolution of *state*.

Implicit Information has the characteristic that we cannot unambiguously assign numerical values to *implicit information* but we can calculate the difference between 2 *implicit* quantities. If particle A is at location x, y, z and particle B is at x, $y + 3$, $z + 4$, then all we have is *implicit information* with respect to the position of A and for the position of B. However, we can calculate that the distance from A to B is explicitly 5. Thus locations and times are *implicit information* while distances and time intervals or frequencies are *explicit information*. Unlike contemporary physics, DTP requires that all velocities are explicit and absolute (in other words the fundamental process of DTP Physics must have access to explicit absolute velocity information, even though we have, so far, found no experimental means to measure it. The same is true for energy and momentum).

A *configuration* has a property called "*locality*". The question "What is the position of a *configuration*?" is similar to the question "Where, precisely, is that cloud?" A cloud is an ever-changing mixture of air, water vapor and suspended water droplets. While most clouds move with the wind, there is an unusual kind of cloud called a "wave cloud" that does not move with the wind. When stable warm moist air is forced to rise because the prevailing wind is pushing it up and over a high mountainous ridge, the air cools as it expands and some of the vapor condenses into a cloud. However, once passed the ridge where the air is free to descend, the air heats up and the water droplets evaporate. The result is that the wave cloud appears stationary despite the strong wind, but if one looks closely it is possible to see it forming on the windward side and disappearing on the leeward side. The wave cloud is stationary despite the strong wind! Like a wave cloud, a *configuration* can be rather large, diffuse and constantly forming on one side and disappearing on the other as it is engaged in translational motion. But every *configuration* does have a location and the uncertainty of the location information affects the property that we call "*Locality.*" The precision with which we can measure the *locality* of a *configuration* is related to the energy of the *configuration*. The greater the energy (or mass) - the more precise the *locality*. This is a simple consequence of the fact that the precision of the information available to determine the location of a particle (by means of an interaction with another particle) is limited by the precision of the *localities* of the two particles. As the number of *tokens* representing the energy of a particle increases, the effective precision of its location (in terms of very small fractions of the lattice spacing) increases. The concept of *locality* allows for a rational explanation for the fact that higher energy interactions allow for more precise positional measurements. In this light the concept that "... the higher the energy, the smaller the particle" turns out to be too simplistic. Finally, the precision with which we can make certain measurements is limited by the unit of action: $\hbar/2$.

Discrete Theoretical Processes (DTP)

The 3 basic and fundamental physical units of DTP are: Time, Length and Action. Only the value of the unit of Action is known at this time: $\hbar/2$.

The real and imaginary *"Substrates",* S_{2t} and S_{2t-1}, are the *local* volumes of 2^{nd} order *discrete* space-time where *configurations* of *tokens,* that represent *information*, are found. At any instant in time a *substrate* of space-time has 2 temporally separate components which, together, are assumed to constitute a region of a discrete 2^{nd} order 3+1 dimensional space-time. In order to have something concrete to discuss we will assume that the *substrates* are essentially the same as a delimited region of space-time; as described in the Salt Model. (A Cartesian Space-Time Lattice of *cells* where every *cell* has 4 *implicit* integer coordinates and where every set of four integers that sum to an even number corresponds to one possible cell at one point in time.) Thus, the overall Cartesian Space-Time Lattice is partitioned into 2 subspaces; the Real subspace and the Imaginary subspace. For the Real *substrate* $x+y+z \equiv 0 \ Mod\ 2$ and $t \equiv 0 \ Mod\ 2$. For the Imaginary *substrate* $x+y+z \equiv 1 \ Mod\ 2$ and also $t \equiv 1 \ Mod\ 2$. The structure of the combined real and imaginary *substrates* is essentially a Face Centered Cubic array. Thus each cell in a *substrate* has 12 nearest neighbors that are in the same *substrate* and six nearer neighbors that are in the other *substrate.* NaCl salt crystals have the same kind of geometric structure.

"*State*" is a property of a *configuration* and a *process.* Consider a photon. Its *state*, at a given instant in time, includes its explicit energy (or frequency), its explicit direction of motion, its implicit position, its explicit speed of propagation and its spin *state*. First, at any particular instant there is an amount of information in a *configuration* that represents, simultaneously, both its energy and its temporal *state*. Second there is an amount of information in a different *configuration* that represents both its explicit momentum and simultaneously its implicit position. The so-called "Uncertainty Principle" can be explained as due to the fact that the same *configuration* represents both position and momentum while another *configuration* represents both energy and temporal *state*. Further, the quantum of measurement in DTP is always equal to $\hbar/2$.

We imagine that the *state* of a photon determines its properties. There must be *tokens* that represent the information, encoded in the linear wave structure, that represents the energy scalar and the planar wave structure that represents the momentum vector of a particular photon. The discrete representation of the *state* of the photon has to contain both the information that defines its properties along with enabling the processes that give motion to the photon and that govern its interactions with other particles. A 2^{nd} order process converts the 2^{nd} order local state information of the photon to its future 2^{nd} order state: $\{t, t-1\}$ into $\{t, t+1\}$, then $\{t+2, t+1\}$, then $\{t+2, t+3\}$... There is no bubble around the photon where it is possible to say ". . . all the cells inside the bubble belong solely to this photon and none of the other cells belong to it." The answer is that a photon is a process that is the result of the temporal evolution of the material and energetic contents of space-time. Thus, at any instant, the question as to "What is this photon and what is not this photon?" has a complex dynamic answer that is the consequence of the operation of the most microscopic process that defines the global evolution of *state*. Even then, there cannot be a simple answer as to which *token* belongs and which nearby *token* doesn't belong as we know that, in the microscopic physics of bosons, there is the obvious property of superposition. There is an answer of sorts, and that is that the most fundamental process along with the *local state*, is what determines the temporal evolution of the *state* of every photon. Therefor, the boundaries as to what is the photon and what is not the photon; are dynamically determined by the fundamental process. What is certain is that various cells at particular instants of time may be, in some sense, part of the informational structure of things more than one single particle.

2.1. *Informational Characteristics*

Within DTP, we assume that the representation of *information* is by *discrete configurations* of *state* that have *meaning* within a particular *context*. On the other hand *entropy* is a physical scalar that is equal to the *Log* of the number of distinct *configurations* of *state* that, basically, do not have microscopic *meanings* within a particular context such as thermodynamics. A *meaning* of a *configuration* is given by whatever *process* interprets it. Thus a given *configuration* can have multiple *meanings* given different *contexts* and *processes*. The best examples of this are that position and momentum are both represented by a single *configuration* while energy and fine-grained temporal *state* are also both represented by a different single *configuration*. Thus we open the door to an extremely simple and sensible explanation for the so called "uncertainty principle."

In 1948 Claude Shannon clarified the relationship between a quantity of information and a system with a number of distinguishable *states*, *S*. For *S* equally probable *states*, the amount of information is log_2 (*S*). In the case where the *S states* are not equally probably the amount of information is given by:

$$-\sum_{i=1}^{1=n} P(S_i)\text{Log}_2\, P(S_i)$$

In such cases the unit of our measure of an amount of information is called "Shannon Bit". Thus a system in one of 1024 equally probable *states* represents 10 Shannon Bits of so called "information" 10 = *Log*2 (1024). A number of Shannon Bits defines a fundamental limit for non-lossy compression of data. For theoretical physics, quantitative measures of the Log of the number of equally probable states of a thermodynamic system are de- fined as its entropy. In some sense Entropy tells us how much information we do not know about the microscopic *state*. Thus we have refrained from relating "*entropy* " to "*information*" for reasons that should now be clear.

3. Philosophical Speculations

There could an interesting philosophical consequence if we were to conclude that some kind of DTP accurately models Physics. There would be the inescapable implication that the DTP laws exhibit rational design. However, there is no reason to fret about that possibility and there is no reason to assume any consequent connection to any of various current or historic religious concepts. DTP could certainly open the door to the plausibility of a more rational picture of cosmogony issues surrounding Big Bang theories.

The idea that the basic most microscopic mechanisms of a discrete model requires that effective Translational Symmetry is achieved by being, in essence, designed into the fundamental laws as opposed to just being there naturally, implies that the microscopic laws of physics reflect a design that could be the product of a purposeful design process. If the concepts discussed herein prove correct, it would suggest that the laws of physics, and the initial conditions (the Big Bang) were, in fact, rationally designed. While humans are the only example of rational thought that we are so far aware of, it is plausible that intelligence has evolved in other parts of the Universe. Rational thought might be more universal than we imagine.

The observations that physics has conservation laws and that the observed universe appears to have come into existence about 14 billion years ago poses an obvious dilemma. We should be willing to admit that there is no sensible model for a Universe simply popping into existence. And aside from matter and energy, where might the Laws of physics come from? If we should discover that a discrete informational process underlies quantum mechanics then there is a more rational philosophical model for the origin of our Universe. We may assume that there is some other place, not in this Universe, which we can call "*Other*".

The laws of physics in *Other* do not have to have much in common with the laws of physics in this universe. In particular, the necessity of a beginning (such as the big bang) does not have to be a property of *Other*. *Other* may or may not have conservation laws. On the other hand, *Other* is likely to also have a 3 + 1 dimensional space-time, but it could have more or fewer dimensions. *Other* would have to be larger (with respect to the total number of possible *states*) than our Universe; likely very much larger. One can imagine that in *Other* there exists or has been constructed a very Large Cellular Automaton (LCA) that implements the physics for our universe and that once the initial conditions were set into the LCA the process was put into motion and allowed to evolve undisturbed. The fact is that, within the laws of physics, the evolution of state is computation universal in the Turing sense. That fact can explain at least one purpose for the existence of this Universe. The purpose is likely to be answering a question that cannot be answered analytically. For example, it is doubtful that there is an analytical process that could answer the following question: "Will there ever occur, during 20 billion years of simulation, a specified, compact amount of some particular kind of matter at a temperature below one nano-kelvin?" Where the assumption is that doing so requires purposeful, intelligent, skillful effort without any useful or constructive motivation for making the effort – beyond curiosity.

Humans are the prototype intellectual creatures on this planet. As politics and wars attest, we are not yet able to always think and act rationally. There is the possibility that we might be superseded intellectually, by combinations of the net and possible AI supercomputers of the future. If so, perhaps such future systems may also be able to better understand physics, cosmology and cosmogony. It might be better to be told, even by a computer, as opposed to remaining ignorant. In the meantime, we might be near to our last chance to discover new science on our own.