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A Universe Without Matter: The Processing of Information/Energy through Discontinuous Space Cells in Two Models; a Computer Simulation, or a Self-Replicating Substrate of Space Cells

David Reardon

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Abstract

Whether the universe is a computer simulation, or whether we wish to efficiently model our universe in a computer simulation, there would be benefits to modeling it in a fashion analogous to computer spreadsheet, each lattice cell can be conceived as containing all the mathematical formula necessary to continuously compute its state relative to changes in all its neighboring cells, and by progression, in relation to all the cells of entire space-time lattice.

Alternatively, the "real" universe may itself be built on a space cell lattice, an irregular foam of space cells, in which each cell may be conceived as a multidimensional cell of distortable space, the shape of which fully describes (a) the four basic forces (gravity, electromagnetic, strong, weak) observed at that cell of space, and (b) the probability (or weight distribution) of any quantum states overlapping the cell and its neighbors.

At an appropriate scale, it would appear that this conceptual model would resolve apparent conflicts between general relativity and quantum physics. It would also provide a new interpretation of Planck's constant as description of the number of space cell events associated with any set of observable events. If formulae operating at a lattice cell level can be improve our ability to understand and model larger scale phenomena, this would be strong evidence in favor of the theory that mathematics is not just a human invention but rather an inherent feature of space-time itself.

Keywords: space-time lattice, simulation hypothesis, grand unifying theory, foundations of physics, quantum information theory, relational quantum theory

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Author Contact: davereardon at gmail dot com

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Introduction

The genius of Albert Einstein was recognizing that every measurement of position and space is relative to a particular frame of reference. Carlo Rovelli's relational interpretation of quantum mechanics takes this concept even further, showing that the quantum states of a system can only be accurately described *relative to a particular observer* (where the "observer" may be any reference point, not necessarily a person).(1) This informs my first premise: *every measurement/observation is relative to its frame of reference.*

My second premise is similar. Information is also relative; it always requires one or more reference points. For example, it is self-evident that human language (and every thought) is built upon layers of symbols, metaphors and analogies. Moreover, every bit of information subject to observation, thought, interpretation, or processing can only be observed and/or processed in relation to other information (for example, in relation to other synaptic reactions in a brain, at the very least).

From these observations (expanded upon later), I can be certain of two things: (a) information exists, and (b) my only access to information is relational; it depends on my own frame of reference (consisting of information Set A, already familiar to me) which is necessary for perceive and process new information (Set B). This premise does not presume that I have correctly interpreted the information available to me (either in Set A or Set B). It simply asserts that information (Set B) is subject to interpretation, the interpretation of which depends on yet another layer of information (Set A).

To these two premises, I would add a third: space is more fundamental than particles. Indeed, my perception of particles is simply an artifact of a perceived space…or more specifically, the processing of information as it passes through discrete units of space.

Obviously, this third premise requires much more defense than the first two. That defense is largely the focus of this paper. For now it is sufficient to state that ever since I was introduced to the fact that elementary particles exhibit wave-particle duality, I have been convinced that the lexicon of physics rests on metaphors that are clearly inadequate and misleading. While the term “particle” is clearly useful in describing how things work on the macro scale, the same word is a misleading, even an invocation of mythology, at the Planck scale. If there is one thing modern science has proven is that that Leucippus, Democritus and Epicurus were wrong; there are no truly indivisible, stable particles.

If, as I believe, elementary particles are not the fundamental building blocks of the “material” universe, what is? My proposed answer: discrete units of space. More specifically, discrete units of space through which energy/information is distributed and in the act of being processed (passing through units of space) in a series of ordered events. This series of ordered events is what we (or from the perspective of each unit of space) perceive as time, wherein each “event” is any change of information contained in a unit of space.

As discussed below, this proposal appears to be consistent with a number of theories proposed by others, including relational quantum theories, information quantum theories, cellular automaton, and theories that the universe is indistinguishable from a quantum computer. It is my hope to contribute to these lines of thought.

In the sections which follow I examine two models of a universe built on a discrete space lattice. First, I consider the possibility that the universe is, or could be, simulated by a computer. Second, I explore how identical behavior could exist in a physical universe that consists of a “physical” space cell lattice, made up of an irregular foam of space cells, in which each cell may be conceived as a multidimensional cell of distortable space, the shape of which fully describes (a) the four basic forces (gravity, electromagnetic, strong, weak) observed at that cell of space, and (b) the probability (or weight distribution) of any quantum states overlapping each cell and its neighbors.

Since both models raise questions regarding the “substrate” upon which either model must exist, my discussion also includes an evaluation of the relevance, or irrelevance, of the substrate question.

The organization of my paper is as follows:

First, I discuss the evidence others have raised for seriously entertaining the possibility that the universe is a computer simulation. Whether or not it is actually a simulation, I argue that the prospect *of being able to simulate the universe* inherently useful and should therefore be pursued, if only to better understand how a universe composed of “physical” space cells must operate. In short, both models of a universe based on discrete space units are deserving of consideration.

Second, I explore the first of these two models, a computer simulation. In this section, I argue in favor of a simulation analogous to a computerized spreadsheet in which each cell represents a Planck-space which is constantly re-computing its own set of probability values relative to all its neighboring cells and, by progression, in relation to all the space cells of entire lattice. Unlike computer spreadsheets that we are familiar with, however, each cell in our hypothesized space lattice might be evaluating multiple equations (a gravity vector, strong and weak force vectors, et cetera) with multiple “instantaneous” values. Moreover, to accommodate cosmological inflation, each cell would contain the programming necessary to replicate itself in order to a create logically adjacent space cells when conditions require an increase of space.

In the third section, I consider the second model, wherein the fundamental building blocks of the universe is a lattice, or foam, space cells (perhaps composed of dark matter and/or dark energy), wherein the four fundamental force vectors and the probability of quantum states

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change the shape of each space cell in a series of events made up of reactions to the changes in shape of all each cell's neighbors, with the speed of causation limited to the speed of light.

Fourth, I consider and adopt as true the theory that time is simply a perception of a specific series of events, and that the proper way to describe fundamental physical theories is by a count of a sequence of events. In regard to the space-cell theory presented here (whether simulated or in a "real" foam of space cells), time is relative to each space cell's processing of a single event, where an event is defined as a change in one or more values defined by the space cell.

Fifth, I examine the implications of the forgoing on understanding Planck's constant. In short, I conclude that Planck's constant is a description of the number of space cell events associated with any *set of events* (a macro-event) subject to observation.

Sixth, I examine the information theory interpretation of entanglement proposed by Cerf and Adami and discuss it in light of the space cells model.

Seventh, I present a defense of the view that information and mathematics are more fundamental as the "building blocks" of the universe than particles, thereby underscoring my argument that particles are an artifact of information, not the cause of information.

Finally, I briefly describe experimental approaches that might be pursued to support or disprove either or both space cell models presented herein.

Following is a summary of key propositions:

1. Energy is mathematically definable. It can be treated as a subset of information.
2. The quantum realm can be completely described as information processing through space.

3. All observable space is made up of discrete space cells having common properties, including the capacity to replicate cells (cosmic inflation) when the energy/information contained in the cells reaches a replication trigger point.
4. The perception of matter (the fundamental "building block" of the universe) is the propagation of energy/information through space cells.
5. Time is a progression of events marked by a change of energy/information in a cell of space. If there is no change in information, there is no elapse of time in that cell.
6. Planck's constant describes the number of events processed by space cells in proportion to the energy and/or mass involved in a specific set of events.

Is a Computer Simulated Universe Likely, Possible, or at Least Helpful to Consider and Replicate?

If the human race had sufficient computing power, and the ability to create artificial intelligence with capabilities approaching that of the human brain, would some of us run computer simulations of human beings, and even entire civilizations of AI beings "living" entirely in a simulated universe?

Of course we would! Even modest game simulations are sufficient evidence of our attraction to such simulations. But beyond entertainment value, the opportunity to create such AI civilizations would help to advance science on many levels. Computer simulations of an entire universe could be used to examine how our own universe works, to conduct sociological experiments, to enlist a billion artificial intelligences to explore solutions to problems such as global warming, or optimization of economic or political structures, or to create and "harvest" great works of art, literature or philosophical insights. Indeed, the "holy grail" of simulated universes would be one in which our AI counterparts would create another layer of AI scientists of varying temperaments and experience in order to harvest multiple layers of discovery and innovation. Indeed, the risk of an AI disaster (à la Skynet), would be a strong argument for confining simulations capable of high intelligence to their own artificial universes.

Inspired by the simulation hypothesis, Nick Bostrom examined the theoretical limits on computer power and he concluded that a complete simulation of the lives of 100 billion artificial intelligences in a simulated universe would require just a miniscule fraction of the computing power of an advanced civilization.(2) From this premise, Bostrum proposes a mathematical proof that:

> "one of the following propositions is true: (1) The fraction of human-level civilizations that reach a posthuman stage is very close to zero; (2) The fraction of posthuman civilizations that are interested in running ancestor-simulations [or any simulation] is very close to zero; (3) The fraction of all people with our kind of experiences that are living in a simulation is very close to one."(2)

The second option, he concludes, is particularly unlikely, a conclusion I agree with, as indicated by the second paragraph of this section. That leaves options 1 and 3. Option 3 is a strong argument for keeping an open mind to scientific inquires that may shed light on whether or not we are in a simulated universe…or, alternatively, how much we might learn through our own efforts to create such a simulation.

Physicists Silas Beane, Zhhreh Davoudi, and Martin Savage were motivated by Bostrum's "logically compelling" calculations to ask how physicists might look for evidence that we are living in a "numerical simulation performed on a cubic space-time lattice or grid."(3) They concluded that any simulation would likely have limits of resolution that might be detectable, suggesting that, for example, that evidence of a "rigid hyper-cubic space-time grid" which might underlie a simulated universe might be detectable through a number of methods. In their conclusions they notably state:

> A number of elements required for a simulation of our universe directly from the fundamental laws of physics have not yet been established, and we have assumed that they will, in fact, be developed at some point in the future; two important elements being an *algorithm for simulating chiral gauge theories, and quantum gravity*. It is interesting to note that in the simulation scenario, the fundamental energy scale defined by the lattice spacing can be orders of magnitude smaller than the Planck scale, in which case *the conflict between quantum mechanics and gravity should be absent*. (emphasis added)

In short, the simulation hypothesis may describe our "real" universe. But if we are in a simulation, it seems highly likely that our simulators would incorporate, as much as possible, the real physics of their own universe into our simulated universe. While they might experiment with slight variations, it is likely that most of the mathematical laws governing their physics would be replicated in our physics. And even if some ambitious programmer created an entirely new set of physical laws for this simulated universe, totally unrelated to the programmers' own "real universe," then invented laws of physics would still be the true laws of physics for our simulated universe and therefore understanding how they can be simulated in our own simulations would reveal how our universe works and can best be simulated.

Bottom line: there is no downside to assuming (or at least being open to the possibility) that we may be living in a simulated universe.

This leads to one of my chief arguments in this paper: a simulated universe may be most effectively constructed around the core idea that space-time is not infinitely divisible. Moreover, if we are not in a simulation but space is still truly discontinuous, then the failure to grapple with this fact would be a major stumbling block in our efforts to understand and mathematically model the workings of our universe. Conversely, even if space-time is endlessly divisible in our

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real universe, there are still benefits to developing mathematical and computational tools to accurately simulate space-time in finite memory array.

Here it is worth noting Nicolas Gisin's argument regarding the impossibility of universal constants being real numbers (which require infinite information).(4,5) Because of this, a computer simulation based on finite information numbers(6) begins with the advantage of avoiding the infinities otherwise introduced by deterministic formulae that require access to constants of unlimited precision. In other words, a computer simulation fits within the confines (and liberties) of intuitionistic mathematics.(5) Similarly, Jürgen Schmidhuber's argues that "any first order theory with an uncountable model such as the real numbers also has a countable model" in his detailed analysis of the limits on theories of everything.(7)

This discussion would not be complete without mentioning the contributions of Marvin Minsky(8), Seth Lloyd(9), Stephen Wolfram(10), Gerard 't Hooft (11), Ramin Zahedi(12), Giuseppe Di Molfetta(13) and Pablo Arrighi(14) in exploring mathematical models of a digitalized universe, most frequently in the form of cellular automata.

In the next section, I look at how a simulated universe may be best structured as on the basis of a lattice of space cells. Then, in the following section, I consider how the same effective structure might exist as "physical" space cells in our true universe.

Model 1: Computer Simulation of the Universe Based on a Spreadsheet-like Structure

Broadly speaking, there are two ways to simulate a universe: particle-centric or space-centric. In a particle-centric simulation, the database would have a row for each particle, with a position and a vector of motion associated with each. In each program cycle, the programming

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would then adjust the position and motion of each particles based on calculations relevant to any interference resulting from collisions of two or more particles. This is how many computer games, such as Pong, were constructed.

An alternative approach would be space-centric. In one variation of a space-centric model of the universe, Stephen Wolfram proposes that all features of the universe are emergent from a network of cellular automata processing causal invariant replacement rules.(15) The cellular automata are related to each other as nodes in a network. The state of each node, and the network states at any moment in time, are entirely deterministic, driven by the replacement rules governing each cell. But even with relatively simple rules, the system is so irreducibly complex that future states can only be predicted by running the entire computation. It is computationally irreducible.(10) The important distinction is that Wolfram's cellular automata completely define both their own state and the rules by which that and neighboring states are processed with each cycle of time. If the replacement rules were completely known, the entire universe would evolve from a single cell beginning with the first step calculation of the first cell. In other words, all the information required to evolve the universe exists within the initial (and everlasting) deterministic replacement rules. The Wolfram Physics Project is an effort to identify the "simple rules" automata in the network would require in order to replicate all the observed effects of experiments in quantum physics, general relativity, and classical physics.

In the model presented here, my goal relative to a computer simulated universe is to lay the ground work for my second model, a "physical" lattice/foam of space cells. Moreover, as I am prepared to accept high computational costs, I am not constrained to finding a "simple set of replacement rules" that can be described using Wolfram's mathematical notation for network node changes. Instead, my goal is to simply provide an outline of a space-centric computerized model of the universe that is easy to understand.

In short, I am proposing consideration of a space-centric database wherein each space cell would be associated with a data array including (a) vectors for the four fundamental forces associated with that space cell, (b) the probability values for any quantum states that may overlap each cell, and (c) a reference link to each of its neighboring cells.

In this model, each space cell is like a cell in a spreadsheet in which the values associated with that cell are constantly being re-evaluated in relation to changes in the values of its immediate neighboring cells, which by extension, are informed by the entire spreadsheet (the entire universe). The speed of values propagating between neighboring cells and being updated is the speed of light, c, which is also the speed of causality. Notably, in keeping with quantum theory and electrodynamics, no single cell in the spreadsheet contains all of the information that represents a single particle. Instead, each cell contains information representing a probability that *a portion of proximate particles* are represented by the information in that cell.

In my conception of a computer simulation based on a space-centric spreadsheet, each space cell would contain the exact same programming, the Grand Unifying Equations (GUE). Notably, the governing program may also include IF-THEN-ELSE logic. This is an important consideration. The premise for including logic functions is that they are widely used in our present computer simulations. In this case, one specific use of such logic functions may be to provide for cosmological inflation. Logically, a provision to create new space cells is especially compelling with the amount of information (the amplitude of one or more the values) in a region of cells exceeds some limit. When this limit is exceeded, the space cell's own logic function would engage to expand the memory array, adding new cells to the spreadsheet, thereby redistributing the probabilities values for all the cells. Obviously, this process is analogous to biological cells which create identical copies of their program instructions (DNA) when they divide into new copies.

Here I would add another possibility, the space-centric structure could also include a particle pairing lookup table. This variation might be necessary to address observations regarding entanglement, particularly the transfer of entanglement via intermediary particles.(16) In this variation, the space-centric spreadsheet would also have access to a particle-pairing lookup table containing the equivalent of a particle identification number that can be used to associate a particle proximate with the space cell to one or more particles with which it is entangled. This particle-pairing table could be used to retain a record of only the most recent entanglement or the entire history of interactions with other particles. Since this table is separate from memory array defining the space cells, each space cell may have instant access to the shared lookup table. In other words, the mystery of “spooky action at a distance” may be explained by transmission of information through a shared lookup table, thereby bypassing the speed of information flow between neighboring cells in the spreadsheet.

Efficiency is always important. Even a civilization with computing power to simulate universes would seek to do so in the most efficient manner possible, either in the most compact or the fastest fashion possible.(7) So from the perspective of efficiency, what are the likely differences between a particle-centric simulation and a space-centric simulation?

First, it is obvious that the particle-centric model requires an absolute frame of reference. The observed effects of relativity would have to be faked for each observer. The space-centric model, by contrast, would fit neatly into the principles of special and general relativity.

Second, since each space cell has the same programming, a space centric design is readily scalable. Even if significant computer power were required for each space cell, the fixed programming could be implemented by means of an application specific integrated circuits (ASIC) whenever expansion is necessary.

Third, the number of space cells in a universe is many orders of magnitude greater than the number of particles. This suggests that a space-centric database would require much more

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memory than a particle-centric simulation. On the other hand, memory reserved for data is just part of the equation for cost and efficiency. The cost of processing the data could be a greater consideration, and as indicated above, organizing the data on a space-centric model may streamline both the programming and execution of the simulation.

Before closing the discussion of a computer simulated universe, it notable that Lluis Masanes, et al have offered a mathematical proof(17) that a universe described by quantum theory, and independent of the substrate upon which the physical system is represented, can be fully represented by paradigm of information units governed by just four postulates: (1) the existence of fundamental units of information, gbits, which interact with each other; (2) continuous reversibility; (3) tomographic locality; and (4) a prohibition against simultaneous encoding. Notably, these postulates are all expressed in terms of possible or impossible states, which is conducive to embedded IF-THEN-ELSE logic. This suggests an experimental results that can only be explained as dependent on “if-then-else” logic would favor the hypothesis that our universe is a computer simulation.

Other evidence may also strengthen the simulation hypothesis. For example, Pawel Caputa et al have offered mathematical evidence which suggests that there may be a close correlation between the laws of gravity and rules for optimal quantum computation.(18) If a body of similar analyzes revealed a number of correspondences between laws of physics and optimal computer computations, these findings would tend to support (though not prove) that our universe’s laws of physics are optimized for a computer simulation.

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Model 2: Space Cells as a Physical Interpretation of the Space Lattice

Setting aside the simulation argument, it is still possible, and arguably likely, that our "true" physical universe is still fundamentally constructed on a structure of discrete space cells. Here it is important to clarify that I am not resurrecting arguments for an aether, the historically hypothesized medium for electromagnetic or gravitational waves. Indeed, it is notable that historically the aether was itself envisioned as a material, particulate substance. In that view, massive objects, like the moon, displaced the aether as they passed through it (like a torpedo displaces water) while wave phenomena rolled through the aether (like an eddy through water).

In the model I am proposing, both matter and waves propagate through space cells like an eddy through water. Both a single electron and the moon flow through space cells, not as independent physical entities, but as distortions of space that can be treated as energy/information. In this model, matter is not more solid than energy; it is just a larger packet of energy that appears to be moving more slowly than the speed of light from our perspective. But here, I should note that the appearance "moving more slowly" may be deceptive. The transverse motion of an eddy in water may be slow, but it is just a small fraction of the motion taking place in the spinning of the water. Similarly, it is quite possible that most of the energy processed by space cells in processing the movement of a large mass is simply not observable as transverse motion.

In this model, all observable space consists of an array of space cells, at least as small, and perhaps orders of magnitude smaller than Planck-space. Each space cell is deformable in three or more dimensions. It is compressed, stretched and twisted by the four fundamental forces and the quantum state probabilities of any proximate "particles." Note, that this deformable

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space cell array is exactly opposite to the "rigid hyper-cubic space-time grid" imagined by Beane et al.(3)

A very notable characteristic is that due to the deformity of space cells, there is no absolute reference for distance. Instead, the concepts of length and volume could be replaced by a count of number of space cells encompassed in a measurement. But for most practical considerations, the average size of space cells (if it were possible to measure them from a fixed frame of reference) will be very stable in any reasonably large sample of the space array.

Speculatively, space cells may share mathematical similarities to strings in string theory. But whereas string theory proposes that the string moves with the particle it represents, I would suggest that if applied to space cell theory, strings would compose the network (fabric) of space with the vibrations corresponding to passage of a particles pass from one string (space cell) to the next. The vibration is the particle, not the strings (space cells) through which it passes. Moreover, since the space cells are deformable, the length of the cells might adjust to the dimension required to maintain the fundamental frequency of the passing wave-particle.

The array of space cells might be analogous to a foam made up of individual bubbles. This variation suggests that each space cell shares surfaces with a number of neighboring cells. The advantage to this interfacing with other cells is that cell's shape and dimensions (which may be in more than three dimensions) are influenced by that of its neighbors, which is a form of communication between the cells. Any new energy/information propagating into a cell from its neighbors both (a) immediately modifies that cell's shape, dimensions, and interfaces accordingly and (b) continues to propagate to one of the neighboring cells by taking the shortest path appropriate for that kind of information (electromagnetic, gravitations, strong or weak nuclear) to the "closest" neighboring cell. Thus, for example, the straight line defined by the path of a photon is naturally defined by the curvature of space cells.

In this conception of the universe, topology is more fundamental than substance. Indeed, the main objection to this conception, is that our common sense demands that any such space cell array would requires some stretchable "substance," like the plastic walls of cell wrap, to define the border between cells. To this objection, I offer three unrelated responses.

First, space cells may be a variation on string theory, as previously suggested. Anyone who can entertain string theory, can entertain space cell theory.

Second, the interface between space cells may be provided by dark matter or dark energy, or both. From this perspective, the difficulty in directly measuring dark energy and dark matter may then be understood as akin to the difficulty of an artificial intelligence in measuring the physical substance of its memory array when it is inherently limited to only being able to observe the binary state of its individual memory cells.

Third, there are at least two reasons not to reject the theory of space cells even if we cannot explain their "substance." First, if our universe is computer simulation it exists on a substrate of circuitry outside our simulation. While we may be able to infer characteristics of that substrate, we cannot actually get an outside measurement from within it. So, the option that we are a simulation is a complete answer to why it may be impossible to ever fully explain, much less examine and prove, the nature of the substrate on which all of our observations depend. Secondly, even if we are not in a simulation, there will always be some additional layer of "reality" (information) which lies behind and in the layer being examined. (More on this later.) Every answer to "Why does anything exist?" invites more questions. If, for example, the existence of a single universe is explained by some mechanism or law of physics providing the potential to create an infinite number of universes, we are then faced with "But why does that mechanism or law exist?" For every answer, there are always new whys. This is not an argument against asking why. But it is an argument for not rejecting answers simply because (like all answers) cannot answer every subsequent why.

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In short, even if a convincing explanation for the substrate of space cells cannot be presented, if a model of the universe based on space-cells can be constructed which gives us a better understanding of our universe, it is worth pursuing. This is especially useful if a model built on space cell topology can improve our understanding of either how the universe works, or how it could be better simulated to advance future research.

Here I would add a couple more suggestions. First, the evidence for cosmological inflation suggests that a theory of space-cells should anticipate a capacity for each cell, or at least a region of cells, to replicate under conditions necessary to expand the number of space cells available to process the energy/information required by them. This capacity may be reversible; it is possible that conditions could exist where one or more space cells collapse into each other.

Second, the idea of a discrete space-cell lattice suggests that there may be an outer boundary—where space-cells lack neighbors, or where there is a capacity to create a neighboring space cell. In this special case, I would speculate that this outer boundary exists when the existing cells proximate to that boundary have such low energy/information that (a) no new space cells are being created, (b) new events (as described below) are rare or non-existent, and (c) if there is any event propagating toward this outer boundary, it always propagates to a neighboring cell that is next to, rather than "beyond" a boundary cell, or result in the replication of space cells necessary to process it.

In the next sections, I will consider the nature of events and time in the context of space cells and offer a reinterpretation of Planck's constant in this context. But first I wish to call readers' attention to the considerable body of theoretical of theoretical analyses relative to discrete space cells developed by Volodymyr Krasnoholovets, Michel Bounias, and Ding-Yu Chung.(19–27) In brief, they propose:

> The theory of real space, as a tessellation lattice of primary topological balls, allows the derivation and the determination of all the fundamental physical parameters,

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such as mass, particle, motion, time, positive and negative charge, monopole, de-Broglie wavelength, Compton wavelength, and spin. The introduction of the notion of motion is equivalent to the appearance of time. The notion of a massive particle is associated with a fractal volumetric deformation of a cell of the tessel-lattice. The motion of such a particulate cell is accompanied by the motion of spatial excitations called inertons that migrate by a relay mechanism, i.e. hopping from cell to cell. Inertons carry fragments of the particle's velocity and mass and are responsible for both the uncommonness of quantum mechanics and the phenomenon of the gravitational attraction."(25)

Examples of other papers on lattice space theory worthy of the reader's further consideration are cited here.(28–36) Of special note are the papers on quantum cellular automata described by Pablo Arrighi and Guiseppe Di Molfetta.(13,14) and the proof by Robert Farr and Thomas Fink showing that Euclidean space is compatible with discrete space, and moreover, if two dimensional space is discrete it must also be disordered.(37)

Events, Not Time, Propagate Matter and Energy

The insightful quip "Time is what keeps everything from happening at once," suggests, in the inverse, that it is only because there are series of events that we can perceive time. If nothing was happening, we'd have no perception of time.

In my preferred interpretation of the space cell models proposed here, time is the result of cause and effect. It is not an independent dimension. It is an artifact of the order of events as processed by the smallest reference point, a space cell.

A strong mathematical proof for this interpretation is offered by Amrit Sorli and Dusan Klinar.(38,39) They show that the modern concept of space-time, in which time is added as a fourth dimension onto three dimensional space, adds an unnecessary complication. While time is certainly a psychological perception, they convincingly argue that time is best understood, and mathematically represented, as a numerical ordering of material changes occurring in space. Time is simply a form of counting a series of events.

Another approach of relevance here is that advanced by Lee Smolin who argues that "cosmological time is a quantum observable that does not commute with other quantum operators,"(40) and therefore cosmological theory would be improved by refocusing analyses on "the sequences and causal relations among things that happen, not the inherent properties of things that are. The fundamental ingredient is what we call an 'event.'"(40)

In the two space cell models proposed herein, an "event" is any change in any value of a spatial cell. In both models, an event occurs when there is an update of one or more values in a spreadsheet cell. In Model 1, a computer system clock could define all cell updates. On the other hand, there would be no need to update a cell if the state of its neighboring cells were unchanged. In the latter case, if an update is unnecessary, the cell would not "age." This distinction is more clear in in Model 2, where there is more clearly is *no external clock* mandating that all cells must be updated at the same, regular intervals of time. In Model 2, it is more clear that time is not an independent cause, value, or force. Instead, time is an effect (an artifact of events processed by one or more cell values), not the cause of cell value changes.

To expand on this perspective, imagine a space cell that is in some remote location in a void between distant galaxies. Its gravity vector is determined by those distant galaxies, and its shape/values my reflect miniscule touch of the other three fundamental forces. In such a case, it is easy to imagine that the computed values/shape of that space would rarely change. But if its inputs are static, so are its values. Therefore, in a computer simulation, it would be waste of

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resources to “update” the values of a cell relative to an external clock when no change in values could be predicted by the lack of any change in values in the neighboring cells. Even if each space cell was allotted its own virtual computer, why expend any machine cycles when there are no changes to its inputs? Therefore, designing the simulation so that space cell updates are driven only by events occurring in neighboring cells, not an external clock, would conserve computational energy.

This design also has the benefit of preserving relativity. Every cell of space simply experiences its own order of events. Every “particle” (a packet of information propagating through space) undergoes its own order of events relative to the series of space cells through which it passes, and any observer of that particle observes a unique perspective of an order of events relative to the perspective of the space cells through which the observer has passed. Time (the ordering of events) is entirely relative.

Put simply, if there is no observable event (from the perspective of a space cell), there is no elapse of time. Time is simply a way in which by which an observer can count changes of information (events); time is not a way to judge the aging of space cells.

Notably, while Nicolas Gisin’s argument for time-evolving processes consistent with intuitionalist mathematics are described as time based, all of his examples, including his “True Random Number Generator”, could equally be driven by a series of events.(5,6)

Implications for Interpreting Planck’s Constant

As previously mentioned, let us assume that energy/information is processed/propagates through cells at the speed of light, c. Each change in the value of a cell is an “event.” Let us further assume that the propagation, at least in Model 2, is analogous to that of a wave propagating along a tense string, or the equivalent to the energy/information seeking the shortest path between its entrance point coming from one neighboring cell and its exit point in passing to another neighboring cell.

These assumptions suggest combining the formulas for the speed of transverse wave for a string, $v = \sqrt{T/\mu}$ (where v=velocity, T=tension, and μ=mass per length of the string), with the formula for special relativity, $E=mc^2$. Since in this model we are assuming that the speed of causation, the speed at which information propagates across a space cell, v=c. Substitution yields $E=m_1*T/\mu_2$, where m_1 is the mass of the "particle," and μ_2 is the linear density of the space cell.

But in this special case, our basic premise is that the only objectively true fundamental unit of length is a space cell. There is no external ruler with which to measure that a space cell is elongated here or shortened there by the forces which surround it. So in this regard an external reference to the length of a space cell is meaningless. The desire for such a measurement is a holdover from other models of physics.

Therefore, in this model, the proper fundamental unit for length (and volume) is a count of space cells, which I will symbolize by Ñ. This means that the linear density of a space cell is $\mu_2=m_2/\tilde{N}$, where m_2 is the mass of the space cell and Ñ=1 since we are looking at a single cell. Substitution into $E=m_1*T/\mu_2$ yields $E=T\tilde{N}m_1/m_2$.

Recall now that mass is an artifact of the energy/information present at any moment in the space cells processing that energy, in this space cell model. Therefore, in the special case of an individual space cell (which is much smaller than any individual "particle") the mass of a single space cell is proportional to the probability of any particle(s)/information being processed by the space cell. For the sake of convenience, we will here assume that $m_1=m_2$ though in a higher resolution universe/simulation there might be any number of space cells per any given weight of probability. The advantage of assuming $m_1=m_2$ is obviously that it transforms the

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previous equality to E=TÑ, which simplifies our effort to develop a fundamental understanding of the relationship between energy and space cells. If Ñ=1, then the energy processing through a space cell in any single event is entirely reflected in the tension (shape) of the space cell.

We also know that this energy is proportional to the frequency of vibration and Planck's constant, E=*h*f. Applied to the space cell model, the shape of the cell is defined by the energy it contains. In short, it is the nature of the space cell to automatically adjust itself to provide the required frequency of vibration.

If we assume (for the sake of convenience) that each space cell accommodates a single vibration, a frequency of *one vibration per event*, then the E=*h*Ñ*.* This suggests that Planck's constant describes an exact limit on the amount of energy that can be processed by any space cell in a single event.

Traditionally, Planck's constant is described in units of Joule seconds, J·s. But since we have already come to the conclusion that time is not objectively measurable in seconds, the proper unit for Planck's constant is Joule events. Since a Joule is an arbitrary amount of energy, *h* might better be described as being in the units of energy·events. Assuming one space cell per event, *h=E/*Ñ. Or conversely, the number of space cells events required for a unit of energy is Ñ=E/*h.*

In summary, the units for Planck's constant, describe an action, the energy processed through a number of space cell events required to process a specific amount of energy/mass.

If the set of events of interest is a planet moving one meter, that macro-event encompasses a huge concentration of space cells, much larger than a similar "volume" of space-cells found in the void between galaxies. Here I use quotes around volume because the term "volume" is deceptive, perhaps meaningless, since space cells have no fixed volume. Each is of a size and shape precisely necessary to process the energy/information it contains from one event to the

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next. One is tempted to say that space cells are more densely arranged in areas of high mass or energy, but the term "density" may also be misleading when volume is relative to each cell. It is not volume or length, but the count of space cell events associated with a set of events (a macro-event) that is always be proportional to the energy or mass associated with that set of events.

Entanglement

A great deal of ink has been devoted to mystery and paradoxes associated with quantum entanglement. In my view the best insight into this phenomena is the Cerf and Adami's analysis based on information theory which demonstrates that entanglement and measurement are mathematically identical.(41,42) Their analysis shows that every observation of an entangled state is the result of new entangled states propagating through a large number of particles (the observer/device) exceeding many orders of magnitude. This propagation "gives rise to classical correlations between the two measurement *devices* while keeping the entanglement between the two particles (particle + measurement devices) unchanged, thereby creating the confusion between entanglement and correlation." (41)

Mathematically this is demonstrated by the entropy diagram for the states of entangled pairs, entangled triplets, and any number of a cascade of entangled particles, which show that all the apparatus and observers, C, that interact with particle A or B of entangled pair A-B cancel out, with the result that knowledge of state B gives perfect knowledge of state A.(41,42) This is shown in Cerf and Adami's figure 3, (reproduced below per fair use), where the 1 in the overlapped section of 3(b) shows there is perfect correlation between knowledge of A and knowledge of B.

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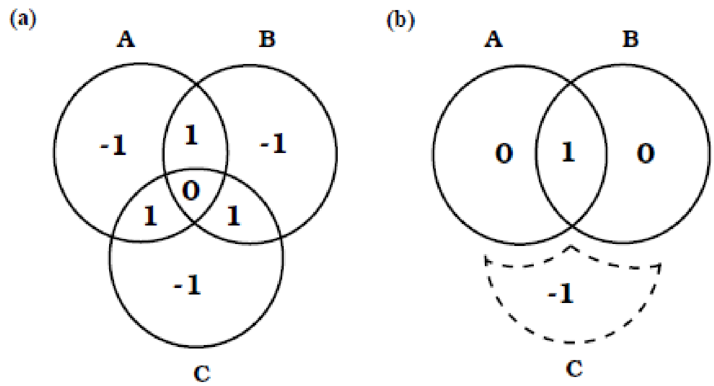
Fig. 3. (a) Ternary entropy diagram for an "EPR-triplet" or GHZ state. (b) Entropy diagram for subsystem AB unconditional on C.



In short, without quantum entanglement it would be impossible to observe quantum events. Or as stated by Cerf and Adami, "Entanglement is the reason that measurement is possible, and thus the reason that the Universe is comprehensible."(41) Indeed, without entanglement there would be no interaction between quantum events, and no propagation of information.

Moreover, the Cerf and Adami entropy diagram of suggests that all the "stuff", C, that interacts with the information bits A and B cancel out. Therefore, if that stuff, C, does not have an independent, real effect, then it is nothing but extraneous information that cancels out, leaving A and B as bits of information that are perfectly paired.

These observation have led Ron Garret to dub this quantum information theory as the "zero-worlds" interpretation of quantum theory, since it suggests since C (in figure 3b, representing everything used to observe an event) cancels out there is not even a single "real universe" (much less a multiverse).(43)

Another implication of the Cerf and Adami entropy diagram can be found by applying it to the penultimate event in a big collapse. Assume that the Big Bang began with a first, single entangled pair, A-B. Then there is multiplication of events during the expansion of the universe even as it heads toward its big collapse. But theoretically, according to figure 3(b) all these other

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events, C, could cancel each other out so that quantum states A and B would be the last two remaining states. Obviously, if A and B were previously canceled out, some other last pair of states could remain, but the implication of the information entropy equations is clear: *both the first quantum states and the last quantum states must be perfectly entangled.*

From this perspective, decoherence may be interpreted as a transfer of the entangled state A-B, to a new entangled pair A-C, where C inherits the state of B and thereby becomes entangled with the state of A. In this process B loses coherence with A but inherits a new coherence associated with the C's previous state. Thereafter, A may exchange state information with particles D, E, and F, resulting in entanglement of quantum states of C-F.

This interpretation is supported by the experiments of Megidish which show that entanglement can be passed to intermediary particles that had no proximity to the "original" entangled pair.(16) This further suggests that the process of observation requires the exchange of entangled states. The only way an observer and observation equipment can remain separate from entangled particles is if they fail to make any measurements. A successful measurement necessitates a transfer of entanglement between the detected particle and the observing system. Notably, this conclusion is consistent with the Rovelli's premise that the quantum state of a system is always a state that is relative to a particular observer (where the "observer" may be any reference entity, not necessarily sentient).(1) In other words, the information about the quantum state is relative to a specific observer/reference, just as the speed of an entity is always relative to a specific observer/reference. Moreover, as noted by Rovelli: "imperfect correlation does not imply no measurement performed, but only a smaller than 1 probability that the measurement has been completed."(1)

From these considerations we can conclude several points.

First, the laws of conservation of energy and matter should be reinterpreted as law of quantum information balance. This law requires that the creation of any new quantum

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information requires creation of least two sets of information such that sum of these sets cancel out.

Secondly, quantum states may be exchanged. This process involves decoherence in relation to a previous entangled state and the transfer of entanglement with a new “observer” particle.

Third, every physical characteristic (speed, position, frequency, spin, charge, sequence of events, etc) can only be described in reference to a specific frame of reference (observer). The idea of identifying the absolute state of the any particle or system at any moment in “time” is only theoretically possible within a single space cell regarding its own state. Even since even this state is always in the process of being both observed and changed by its neighboring space cells, this state is always in the process of change (or, is awaiting change, when there are no proximate events, and therefore no passage of “time.” In short, everything that can measured or observed must be qualified by the limits the accuracy of relevant to the differences in the frames reference between the observer events and the observed events.

Still, it is worth noting that according to the premises of space cells theory, the frames of reference are finite. The total number of frames of reference is equal to the total number of space cells. The total number of events processed is finite. Cause and effect remain intact.

Information and Mathematics are More Fundamental than Matter

One of the deep and profound surprises of modern science is the observation that mathematical equations correctly predict the workings of nature.(44) In one sense, mathematics appears to be a collection of abstract ideas: premises, hypotheses, and proofs.

Indeed, many mathematical relationships can be defined and logically proven to be consistent and true even when there is no relationship to counterparts in the material universe. Somehow, these abstract ideas, conceivable by human minds, can map with near perfection the world we live in. Indeed, the utility of mathematics in describing real things has led Max Tegman to propose that any true mathematical structure must eventually be embodied in at least one one of many multiverses, the set of which includes every mathematically possible universe.(45)

Yes, the universe can be described with mathematics. But is there something even more fundamental than mathematics? Yes. Information. Mathematics describes relationships between sets of information. Without a starting pool of information, there could be no mathematics.

Approaching this subject from another angle, the starting point of every philosophy must begin with an *a priori* acknowledgement of information's foundational supremacy. This is so self-evident that it is often overlooked, as seen in the example of Descartes famous first premise: "I think, therefore I am." But, as many subsequent thinkers have challenged, how can I be certain who or what "I" am . . . and whether it is actually "I" doing the thinking or some computer simulation or a schizophrenic imitation of my real "I"?

Still, the phrase "I think" in Descartes first premise is indisputable. No one can deny "I think" without first experiencing a thought, thereby proving it is true. But even this certainty is laced with a new uncertainly, for while I must agree that "I think," I also know my thoughts are often untrue. The challenge is to know anything with certainty.

So what can I know with certainty regarding my thoughts? They all share one common denominator: information. I cannot be confident that my perception of information is always accurate. But I must agree that I am processing information. Rightly or wrongly perceived, or even if it is only created by my own imagination, information exists.

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That is a firm foundation for any philosophy: “I think, therefore information exists.”

Building on this foundation, I can immediately observe there are many layers of information. Each layer is supported by a lower layer. For example, a printed sentence rests on both a layer of words and a layer of syntax, which requires a layer of letters and punctuation, which requires a layer of defined shapes and a substrate for recording the shapes, and that substrate layer itself requires some structure, shape, and chemistry based on layers of interactions between molecules. And the interpretation of this printed sentence also involves layers of information which encompass the capability of decoding that printed sentence, including photons that selectively reflect off the printed surface that can be focused on my retina, encoded by neurons, and translated by my brain, interpreted by my language, and judged by my intellect. There are layers upon layers. Indeed, there are so many layers that can never claim certainty that we have identified, much less understood, every layer necessary to the whole.

Similarly, mathematics is layered, with higher order mathematics being dependent on lower order.

In short, there is nothing that we can perceive that stands alone. All observable information is connected to other layers of information.

From these considerations, it is at least tenable to assume all our observations of physics are truly just observations of information processing. If this hypothesis is true, the processing of information may take place on a quantum level. In each event where information changes, a space cell event occurs. By observing one or more of these events, we may deduce (but can never directly observe) the mathematical abstractions (or the object code) governing these events. That is at least one of the goals of science: to understand events, perceived as information, governed by immutable rules of information processing.

From these observations I conclude that information surely exists but that it not possible to identify the first bit(s) of information, or perhaps even the first layer of information, from which every other bit or layer of information was derived.

To this I would add, as a likely speculation, that the “first body of information” almost certainly entails more than one bit of information. Indeed, it seems certain that the “first body of information” required not only multiple bits of information, but at least two layers of information: a layer to encode and a layer to decode.

In short, the indisputable fact that information exists, in combination with the fact that everything else includes some portion of uncertainty (indeed, the genius of quantum physics is turning the uncertainties of our ability to observe reality into meaningful probabilities) is a major factor in my personal decision to embrace the idea that all of physics can be best understood from the perspective of information theory.(41,42)

For those seeking to answer “why does anything exist?” or “what is the first uncaused cause?” the premise that there must exist a layer of information that is itself uncaused is the foundation for all that exists will not be satisfying. It may not be fully satisfying, but it is reasonable. Indeed, as argued above, it is the skeptic’s criticism of any theory that fails to answer all questions which is truly unreasonable. There will always be some layer of information, some substrate, below that which can be observed, that cannot be fully examined much less fully explained.

Bottom line: a universe composed entirely of information processing is reasonable, and given the evidence, perhaps the only reasonable premise for understanding the structure and workings of the universe.

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Another Line of Investigation—Another Double Slit Experiment

The space cells model has obvious implications for interpreting results of double slit experiments. Most importantly, in typical double slit experiments the state of the apparatus is itself represented in the state of each space cell through which the information wave/particle is passing as it approaches the slit. The opening and closing of each slit, for example, will subtly change the values/shape of all space cells leading to and from the release point of the particles which are the subject of the investigation. In other words, the space cell model suggests that changes in the setup of an experiment are necessarily propagated at the speed of light as information "known" throughout the experimental apparatus.

If this is true, a variation on the double slit experiment may be able to substantiate the existence of space cells in the following way. If the sequence of events were arranged such that the second slit was separated from the first slit by a space that was greater than the distance between a photon and both slits, then the speed of light limitation on the exchange of information between the two slits would be greater than that of their interactions with the photon. In this arrangement, the photon wave would be in a position to interact with the newly opened second slit before the first slit could interact with the opening of the second slit. That suggests that the photon may interact more as a particle than a wave if and when a second slit can be opened closer to the particle than the first slit. Another problem is introduced, however, since information regarding the change of the second slit will also propagate through portions of the detector at the speed of light, with different angles affecting the timing of both the effects of the slit change and the detection of the photon. In addition, the premise that distance it itself an inexact measurement, given the distorted shape of space cells, this experiment may not be conclusive.

Finally, as previously mentioned, to the degree that any laws of physics may be shown to depend on IF-THEN-ELSE logic, this evidence would favor the conclusion that we live in a simulated universe.

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