Digital Mechanics

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Preface

The Amazing Glorious Gift

Somehow, when I was still a child, I was given a wondrous gift. I don't know how or why; I didn't even understand or appreciate it for decades. Neither did I realize that, apparently, this gift was given only to me. As the vast implications began to filter into my consciousness, my first reaction was to try to share my gift; but it was not to be.

The pieces first started to fall into place some 20 years later, about 1960. Since then I have been able to glimpse and learn more and more about something unknown to others. Over many years this vision slowly transitioned from totally murky to almost clear in certain directions. Puzzling aspects have loomed like great glaciers, which only revealed their secrets as they quietly melted away. But still, even stranger than the Gift itself, is the fact that it has remained mine alone for all these years. I never ever thought to keep it a secret. In fact I sort ran to the rooftops and shouted to all who might listen "…maybe this is it, this could be how things work…" but no one has ever understood what I was trying to say.

My reaction was always strange. I knew how beautiful it was yet I never had any concern for all those who couldn't understand. But now, the biggest picture is starting to come into focus and the totality of this amazing glorious gift is slowly being revealed. To me it is so staggering that I must try once again to pass it on to others. It's made difficult by my refusal to treat these concepts more modestly or more conventionally. It's not that I am immodest or unconventional, it's that the subject matter is totally revolutionary and to understand it or even evaluate it requires an open mind. More specifically it requires one to change their frame of reference so as to have a new viewpoint. One cannot understand or appreciate what is revealed here except from the vantage point of the Digital Perspective. I will try my best to explain all this so that you might be able to share what I have seen. You can read about it here. You should be able to understand it. But it's far out, hard to swallow, difficult to digest. And when all is said and done, it might still be mine alone.[1]

As a child, I loved arithmetic and mathematics. I could understand the process of doing addition. Because, in some ways I was slow to get educated, I was allowed the pleasure of discovering many mathematical ideas for myself. This ranged from Fermat's Little Theorem to the binary number system. As time went by I came to realize that 99% of my mathematical discoveries were old hat, with most

[1] Of course, this is an exaggeration. Other people have shared some aspects of my vision. Most notable was Konrad Zuse. Today there are scattered throughout the world a very small number of individuals who have some similar thoughts such as Joel Dobrzelewski or Plamen Petrov, but I know of no one in the Physics Establishment. Many of my colleagues and students understand my vision, but none that I know of admit to believing in it.

of them thought of by Euler.

I don't know exactly when I first realized that the way I thought was different. When I was young I thought that those differences reflected something wrong with me. I couldn't seem to accept things that everyone else seemed comfortable with. I couldn't figure out things that others could easily figure out. My mind seemed to me to be in some ways defective even though I knew I was smart. I puzzled over simple things, such as trying to understand exactly what kind of machinery could be at work so that the progeny of two living things could inherit traits from both of them. Sex was complicated enough but inherited characteristics posed the same problem I saw in Newtonian motion. I now understand that what I wanted to know in detail was how the informational process worked. What was it in a seed that determined the color of the petals in a flower? What was it in a particle that determined the speed with which it moved? What was the mechanism that led to Mendel's[2] laws? What was the mechanism that led to Newton's laws? I knew that if a pea plant with red flowers and one with white flowers produced a seed, that the "red" and "white" had to be written somewhere and somehow in the seed. I knew that when two particles were about to collide, somehow, in some kind of language, the momentum of each had to be written down in some way associated with each particle. During the interaction this information had to be combined then re-divided between the two particles. I mistakenly thought Biology too complex to be understandable at the level I was seeking; I mistakenly imagined that physics ought to be easier. I merely wanted to figure out, in perfect detail, how that information had to be represented and how the informational process that we call "physics" functioned. But at the time, I didn't even know how to state what it was that I wanted to figure out. I was not only missing a key, but I didn't even know the language in which to describe the problem. My friends, who also liked math and science could neither understand what I was looking for nor understand why I persisted in such folly.

I was seeking a different kind of *understand*. Mathematics deals with many kinds of numbers. The integers, 0, 1, 2, 3… are not too hard to understand. The rational numbers are easy too since each can be represented by two integers, e.g. ¾. Yet within mathematics are all kinds of other numbers such as irrational, real and transcendental. These numbers, most of which cannot be written down exactly as an ordinary decimal, include the square root of 2 and Pi (Approximately 1.4142135623730950… and 3.14159265358793… respectively). We can represent the square root of 2 exactly by the symbol $\sqrt{2}$ and Pi by the symbol π. What we cannot do is to write down an exact representation as a

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[2] Gregor Johann Mendel, 1822-1884, discovered the laws of heredity. Working with garden peas, he found that there were dominant and recessive genes. Before Mendel, it was widely held that offspring more or less blended characteristics of their parents. Mendel discovered that inherited traits came in two kinds, recessive and dominant, where purebreds expressed their trait and hybrids only expressed the dominant trait. Further, of the offspring of a purebred dominant trait and a purebred recessive trait, ¼ were purebred dominant, ¼ purebred recessive and ½ hybrid, showing only the dominant trait. This changed the picture of inherited characteristics from some kind of continuous blending of all one's ancestors traits, to a simple discrete process. It was a kind of atomic theory of genetics; now understandable as a consequence of processes involving DNA.

number, just with digits. This means that arithmetic with such strange numbers cannot be performed as with the integers. I had to learn that one could *understand* these strange things exactly, but not as numbers with digits. In a sense one had to *understand* the ideas about these strange things without understanding the digital, numerical representations themselves. This was annoying to me, yet among my acquaintances who were also interested in math and physics, none of them shared my problem.

When I learned about Newton's laws, I was told that they were the laws of motion. So be it. With Newton's Laws I could solve homework problems. But even with them, I still couldn't *understand* motion. I couldn't conceive of what sort of thing could be going on that allowed a body to move relative to other bodies. The problem of motion became of overwhelming interest to me. My first observation was that a particle in motion had to know what it was doing. If I thought about an isolated particle coasting along with no forces acting upon it, I wondered "How can a particle remember, from one instant in time to another, which way it is supposed to be going?" Why don't particles go in random directions and at random speeds? I couldn't ask anyone these questions without their thinking of me as an idiot. Of course I learned about Newtonian Relativity and Conservation of Momentum, but those were only confirmations of the mystery; just different ways of stating the same observation that somehow objects do mysterious things: they move, and they remember what they are and which way they are moving.

To me, remembering which way something was moving can be facilitated by writing it down. "I am moving due North at 3 miles per hour." If it is written down, then there is no problem remembering what it is. However, then we have the problem that something must read what is written down and actually translate that into motion. Even though I was never taught anything about writing things down being a part of physics, I realized that there was a hypothetical way to read what might be written down. I imagined a magic magnifying glass, that could look into space and matter, in any degree of magnification desired, and which could reveal to me anything contained in that space or matter. OK, if someone looked in the right place, near a particle, they ought to be able to see the equivalent of "I am moving due North at 3 miles per hour." I knew enough to realize that I was going against almost every holy principle of physics. Of course, concepts like "3 miles per hour" or "due North" were very unlikely to be shared by an idle Helium atom that just happened to be cruising along, due north at 3 miles per hour in my reference system. Well, what physics taught me is that all coordinate systems, in rectilinear motion were equivalent, so relative to all the arbitrary equivalent coordinate systems the velocity of the Helium atom could be written down as absolutely anything (within speed of light limitations).

The fact that it could be written down as anything, did not impress me, because I knew that it had to be written down as something. By "written down" I didn't mean written in Arabic Numerals. What I meant was that there has to be some kind of information that in some way represents the motion of a particle, just like there has to be information in a seed that represented the color of a flower. Then there has to be some kind of process that translates that information into changing the position of the particle, just like there has to be some kind of process that changes a flower seed, no part of which is colored red, into a red flower. When a particle accelerates, there has to be some kind of process that takes the information that represents the force, and uses that information to change the information that represents the velocity.

I was sure that we would know the solution to this problem in Physics before it could possibly be discovered in Biology. To me physics was the King, married to mathematics, the Queen and mathematics was a pure and logical structure. Biology, on the other hand, was wet and squishy, amorphous and messy. It seemed only distantly related to mathematics. It was astonishing to me to see how wrong I was! We now know that the color of a flower is indeed written down in a language, one that has a 4 letter alphabet[3].

All this was the basis of a general uneasiness that persisted throughout my formal education. I tried to suppress it because it seemed useless to try understand all these things. It seemed to me that I was like someone trying to understand ordinary physics, before the invention of mathematics. Some great tool or formalism that was needed had either not yet been invented or perhaps was something I had never heard of. It was too soon for me to be able to understand anything about information processes and bits. But I am very stubborn about intellectual concepts. While I was a student at Caltech, I loved learning how to do physics, but I never, for a moment, thought they were teaching me what I really wanted to know.

What I find so weird is how other people react to what they learn in physics. The problem of one's true understanding seems to only come up when physicists are learning Quantum Mechanics[4]. No one understands the physics of Quantum Mechanics in any intuitive way. Nobody does, because QM is not like anything anyone is familiar with. Of course, in due time, a physicist can be at ease with QM and can develop intuition about QM, but its never quite the same as intuition for Newtonian Mechanics. Physicists have to master the tools of QM, so they can do the calculations necessary to get good grades, finish their PhD's, discover new things and publish papers. But they never gain the feeling of intuitive understanding that they all have for Newtonian Mechanics. Graduate students learn to accept the dictum that they must master the mathematical tools of Quantum Mechanics while banishing from their minds the fact that they don't have a clue as to what's really going on. While a freshman at Caltech, I brought part of this question (about the lack of intuition re Quantum Mechanics) to Linus Pauling[5], who lectured Freshman Chemistry. His reply was to bring up the wave and particle nature of the constituents of physics. He told me that while

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[3] The 4 letters of the DNA alphabet are adenine (A), thymine (T), cytosine (C), and guanine (G).

[4] Quantum Mechanics is the physics of microscopic phenomena, such as interactions between sub-atomic particles. The laws of Quantum Mechanics are very strange and bizarre, yet they very accurately represent the statistical behavior of subatomic events.

[5] Linus Pauling was the only winner of 2 unshared Nobel Prizes, the first in Chemistry, 1954 and the second for his peace efforts in 1962.

sometimes you had to look at an electron as a point particle and while at other times you had to consider the electron's wave structure, there was building in his mind something he called "wavicle"; a conglomeration of characteristics that embodied both viewpoints. However this struck me as no more than a way to feel better about the nature of an electron, as opposed to finding out more about an electron's true, fundamental nature.

Wow! I certainly couldn't understand how Quantum Mechanics works. I had learned the tools of good old Newtonian Mechanics and couldn't understand it either. I had never heard of anyone else, in recent times, being so afflicted. In order to get on with life, I quit Caltech (while a sophomore) and joined the Air Force to become a fighter pilot.

Being an Air Force fighter pilot takes some concentration, so I took my basket of insights and mental confusions, boxed them up for later reference and buried them in my unconscious to await something that would straighten me out.

In my early 20's (in 1956) I got into the computer field. I was still in the Air Force, in the Research and Development Command and was assigned to MIT's Lincoln Laboratory. Lincoln Labs was applying the most advanced computer technologies in the world to the problem of defending our country from attack by conventional bombers carrying nuclear weapons. Radars could spot and track the bombers, and guide our fighter to intercept them and shoot them down. The idea was to create the *Sage System*, using computers to digest the radar information and to allow accurate directions to be given to the fighters that might be intercepting the bombers.

It was a wonderful time, because I had the opportunity to rapidly learn almost everything known about computers. I plunged into all this with great energy and enthusiasm. I used my new knowledge to solve various problems, taught little informal groups about how to program and, in general became a sort of hot-shot programmer. In 1958, a few months after I left the Air Force, I went to work for J. C. R. Licklider at a Cambridge company called Bolt, Beranek and Newman. Lick, as he was known, was the first person I had ever met who appreciated me as an original thinker, though I never told him about my theories. He gave me great encouragement and taught me how to do scientific research.

Sometime in 1960 everything began to jell. While the Mathematics of continuous variables reigned supreme as the Queen of both Classical Physics and Quantum Mechanics I was certain that something else had to be the Queen of the most microscopic and fundamental processes of physics. It couldn't involve continuity; it had to be a kind of digital informational process similar in some ways to what goes on in the innards of a digital computer.

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Introduction -- "All is Number"[6]

Digital Mechanics is the heart of a new approach to understanding the nature of our Universe. It all starts with the single but unverified assumption that we call "Finite Nature"; that ultimately Space-Time and all other quantities of physics are discrete.[7] The consequence of Finite Nature is that our conceptual, philosophical framework for understanding physical processes undergoes dramatic change, despite the fact that the mathematical laws of physics remain largely the same. Digital informational processes then assume primacy over all aspects of microscopic physics. Most of the mathematical functions of continuous variables used in physics become accurate approximations to reality, as opposed to actually representing reality. Some laws, such as the Conservation Laws remain exact but discrete.

In the coming pages we will be explaining the "Digital Perspective" wherein we show how to look at things and concepts from a new point of view. We will discuss certain aspects of computation. We will then look a bit at conventional physics taking the Digital Perspective into account. Finally we will define some DM models and explain how the quantities of physics are represented by DM

One goal of DM is *physics* devoid of what we call "magic". DM can give us the ability to exactly understand how the most microscopic laws of physics work, what a particle is, how things move and interact. Rather than discuss the many kinds of possible DM models, we will here describe a few definite models. These are *wrong* models that spring from our imagination yet they embody many ideas and principals that we believe will characterize some accurate future models. DM is not yet a viable theory; it merely illustrates how certain aspects of a such theory might look.

DM turns almost every fundamental concept of physics on its head. In the lowest level of DM, there are atoms of energy, momentum and force. DM has no need for particles as entities separate from the theory; they arise from the theory. There is an absolute reference frame and there is angular anisotropy; both accessible to the microscopic process. Nevertheless, we will give reasons why such simple yet bizarre substructures have the potential of being correct models of physics. DM offers the possibility of underlying mechanistic explanations for all aspects of physics along with useful insights into certain problems of cosmology and cosmogony.

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[6] XXXX an ancient Greek ….

[7] This is the "Finite Nature" assumption, see chapter xxx.

A Glimpse of Digital Mechanics for Scientists

DM is a Unified Discrete Field Theory of Physics wherein all particles, all their characteristics, all the numerical constants and all the laws of physics are emergent properties of the field. DM is totally defined by 8 constants. There are just three natural units, B, L and T. B, is the unit of information and has the dimensions of ∇, L is the unit of Length and T is the unit of Time; all discrete. A natural consequence is that all quantities of DM, such as charge, spin, momentum, rest mass and energy are also discrete. The constants include the 3 units B, L and T all with value 1, the number of spatial dimensions D=3, the number of time phases P=6, and the age of the Universe, A, (an integer multiple of T) are 6 out of the 8 constants of the theory. The 2 others are large integers, each similar to a computer program. One constant specifies the Rule of a Cellular Automata and the other the initial conditions. If DM is a correct theory then the 8 fundamental constants exactly define the past, present and future of the entire Universe, down to the most microscopic states and up to positions of all the stars. The only new calculations that DM might allow us to perform would be about the most microscopic events of physics. This might include the characteristics of the particles and the derivation of the known laws of physics. It is the in the nature of the DM theory that implicit in the constants are all of the laws of physics, the origin and eventual fate of the entire Universe along with the names of all future winners of the Tour de France. However, DM does not allow any of us, the inhabitants of this Universe, to ever calculate any exact state of our world; past, present or future.

The Elimination of Magic

We mean something very specific when we have as a goal, “The Elimination of Magic.” With the exception that our philosophy brings the mechanisms of thought and physics together as informational processes, we side with René Descartes. We should be able to understand everything. Of course, we are not referring to the *magic* of conjuring or the occult and all that. We are referring to things that we observe but which lie outside of the current framework of physics. In other words, there are concepts and numbers, for which physics currently has no models or explanations. Some examples are well known, such as: Why are there the particular particles that we observe? Why so many fundamental constants? If there were no particles, a field theory might not need magic. On the other hand, Physics might also have to resort to “magic” to explain in detail something as common as Newton’s Laws, e.g.: “A body in motion continues its motion in a straight line unless acted upon by an outside force.” This surprising conclusion is reached via the Digital Perspective that simultaneously illuminates the problem and suggests a solution. The current approach in science is to be happy with Newton’s Laws, and to forget all thoughts as to what might really explain motion. Once one understands certain basic principles regarding information, it becomes clear that modern physics really has no explanation for the simplest aspects of mechanics. Up until now, hardly anyone is worried about it. We have all ascribed to Newton's Dictum "I make no hypotheses." A good dose of self-hypnosis starting at an early age and ignorance of certain laws about information, allows us to work in peace. The laws of physics work; they let us use mathematics to get the answers to problems. We have discovered near miraculous mathematical relationships and formulae, but the Laws do not admit of any satisfying, ultimate explanations.

A very careful analysis of the information obviously present, which is represented by two nearby particles moving with respect to each other in rectilinear motion, has no fundamental explanation in current models of physics. Information is present in the form of relative velocity. But where is the information? How is it processed as a particle accelerates while falling to Earth, thus changing the information? What happens to it as the particles interact and then separate from one another? One can argue that we know everything that we need to know, but what we do not know is exactly how it is that an object moves or what about the particle gives it its physical properties. The educational processes that produce physicists seem to be part of an unplanned conspiracy to make them ever more unaware that there are such problems.

DM offers the opportunity of putting a spotlight on these problems, so that they become glaringly clear. DM illuminates certain forgotten problems while pointing to plausible answers. With DM, we start with perfectly understandable models that seem reasonable and actually quite charming; they only suffer from being wrong. DM is in its infancy while physics and mathematics have developed, evolved and matured together. We know so, so much about physics and mathematics. Getting a brand new approach up to the current standards of modern mathematics and physics is not easy. Imagine, DM must relegate the calculus to being nothing more than a handy way of calculating close approximations to what is happening in physics. In DM we have found a way to look for what Einstein was thinking about in 1954, "…a possibility to avoid the continuum (together with space and time) altogether…"

If Finite Nature is true, then DM must revolutionize every aspect of our understanding of the fundamental underpinnings of physics, particle physics, high-energy physics, relativity, quantum mechanics, the Standard Model and on and on. What we hope for is that what we present here can be improved by making it a more accurate model of physics, without ever having to give up its feature of perfect understandability at the most microscopic level. Indeed, that has been a constant feature of progress in DM theories for the past 40 years; many very basic inconsistencies have already been eliminated while more and more attributes of physics become represented within the model. We can assure the reader that DM, as presented here, has undergone a series of dramatic improvements over the last 40 years. Of course this is also related to how bad the theory used to be! We see no reason to suppose that the process of steady improvement will end before DM can become a good model for the most microscopic processes of physics. Of course, all of the above rests on the Finite Nature assumption; only experiments will settle that question.

Given a new perspective gained through the study of DM, we begin to see magic in ordinary models of physics almost everywhere we look. Progress in physics has allowed us to relate more concepts to other concepts. We can calculate more and more. We have a number of important universal laws. We understand features of one level of structure, such as simple chemistry, on the basis of an underlying level; in this case, QED (Quantum Electro Dynamics, which is most basically the physics of electrons and photons and charge interaction). The Standard Model gives a simplification to the plethora of hadrons (particles such as nucleons and mesons that are made up of quarks and gluons; protons and neutrons are familiar hadrons found in the nuclei of atoms). On the other hand, what is the mass of a quark? Why do quarks and gluons have the properties we ascribe to them? What exactly is QCD color? The Standard Model gives answers to many such questions, but it is all mired in complexity.

We use theoretical physics to calculate the outcome of experiments with ever increasing accuracy. We have constructed a fabulous hierarchy, from physics to chemistry to biology. Within the physics of gravity and motion we have gone from Galileo and Newton and the motions of projectiles and the planets to Einstein and Hawking, Relativity and Black Holes. The development of QM, QED, and the Standard Model has been an incredible journey. The journey has taken us upwards into the Universe and downwards to the substructure of nuclear particles. Yet however far down we have gone into the micro-world, the bottom seems as far as ever. Today we have almost no clues as to where the bottom might be and what we might find there. Many workers talk about Planck's Length (around 10^{-35} meters) but no one knows if it is significant or just numerology. If there's physics at Planck's Length, it's a long ways down. From a fermi (10^{-15} meters, about the size of a nucleon) to Plank's Length is a ratio similar to the size of the Sun compared to the size of an atom! And between the particle and Planck's length, we might find as much rich phenomena as lies between things the size of stars and things as small as atoms. All this is to say that at this time, the concept of physics continuing down until Planck's length ought not to be taken too seriously. DM offers a concrete way to reconcile very microscopic phenomena with a not so microscopic lattice spacing.

Maybe through models such as DM we can gain absolute and fundamental understanding of the most microscopic aspects of Physics. There is no law forbidding such a thing. We would like it if things become simpler as we delve deeper. While often true, sometimes it's not true. After all, molecules are simpler than microbes, atoms are simpler than molecules and particles such as electrons and photons seem simpler than atoms. As for nucleons, what were once thought of as simple protons or neutrons have had their models complexified through the Standard Model. As we push deeper into high energy physics, some things get simpler while for others, complexity seems to increase. The idea that one might need to perform 10^{20} arithmetic operations (in a computer) to obtain an inaccurate estimate of the mass of a subatomic particle should tell us something; maybe we have the wrong model?

The Digital Perspective

Die ganze Zahl schuf der liebe Gott, alles Übrige ist Menschenwerk.[8]

We now have a good 50 years of experience with computers. We have learned a lot and there is more to be learned. By working with digital logic circuits, doing computer design, thinking about automata theory, inventing algorithms, debugging computer code, defining programming languages and in general, living up to our eyeballs in bits and bytes, we have learned something. The something we are referring to has not even had a name, so we will correct that deficiency by defining "The Digital Perspective". Our new understanding allows us to come up with new kinds of precise definitions for many concepts that are commonly used in natural language. As an example, we will give a definition for the words "mean" and "meaning" as in the sentence "What do you mean by 'meaning'?"

By "Information" we mean:

Pertaining to the arrangement of things that represent discrete, digital information, independent of what the things are. For anything that is said to contain information, there is always a process which can convert that information into structured digital data (bits). In a computer, information is usually in the form of bits (binary digits) organized into words (some small number of bits, today 32 and 64 are popular word lengths). Whatever the representational scheme of any particular kind of information, there always is a process that can convert the information into bits. In a mathematical sense, it is equivalent to say "Digital Information can always have an exact representation as structured sets of integers."

It is an absolute implication that when we call something "information" that there is meaning associated with the information, and that the information is in a form amenable to being used, communicated or modified by an informational process (basically a person, other creatures or some form of generalized computer). Such digital information can be static, fixed and unchanging, (such as so called Read Only Memory), printed literature, or music that has been recorded) or dynamic (engaged in information processing, sensing, control or communication, such as the memory contents of a working computer or music being played from a computer memory. Dynamic digital information is engaged in an informational process (computation) where, consequently, some of the digital information may be changed in order to change the associated meaning. A copy of static information can always be made dynamic; the static information is read into a computer and the copy in the computer may become dynamic. A most important principle is that information cannot have meaning outside of the context of the corresponding informational process that gives it that meaning. That process may take place in a computer, in a brain and nervous system, and in the DM models of physics, in the most microscopic processes of physics.

The Digital Perspective is a different way of looking at things. It gives us a new view of our world. It is different from preexisting philosophies, mathematics,

[8] God made the positive integers; all else is the work of man. Leopold Kronecker

logic or science. Today, much of human society is immersed in computer technology; but almost no one suspects that an intellectual revolution may be just around the corner. Of course, the concept of information has been around, in one form or another, for a very long time. Man is not just the tool-making animal. Man is the informational animal. With speech and natural language humans have communicated information to each other with speed and efficiency that has been unmatched by any other creatures on the planet. Whales may sing to each other over vast distances, but humans plus technology communicate on a vastly greater scale. The written word was a fantastic informational invention, followed by books, printing, and finally technologies such as electronics and digital systems.

The telegraph, telephone, radio, television and internet are all informational systems wherein communication has speeded up and expanded so enormously that it is qualitatively new. Every aspect of handling information reaches its apex in the development and application of computer systems which changed all the rules as to how information gets stored, accessed, communicated and processed. Today the final switch to Digital is underway in earnest. Music on records was analog, now it's digital on CDs. Movies were once limited to film or videotape but are now also in digital form on DVDs. Soon, all information storage and communication will be digital. Something big is happening but it's not all computers, internet, commerce and efficiency.

What should be seeping into our consciousness' with the Digital Perspective is a new way of looking at the world. Digital! The discoveries and inventions of Mathematics, during all of the past several thousand years, gave us a new perspective and enabled the maturation of societies' various arts and crafts into today's science and engineering. Trying to comprehend all the wondrous connections between mathematics and engineering, the sciences and especially physics, is overwhelming and sometimes intimidating. Yet the Digital Perspective has prospects of becoming bigger and more pervasive than the Mathematical Perspective. We are not referring to the use of computers so much as to the new ideas and concepts related to things digital. We already know as a certainty that the Digital Perspective cannot replace mathematical thinking. It is not a competitor; but it is able to do what mathematics cannot do. It will surely cause a revolution in the human understanding of much of what we can know. What we are doing here is taking the Digital Perspective and applying it to *physics*. This is not because things digital are in vogue. It's because, while barely able to comprehend all the possibilities, we have been struck by the amazing correspondences between the task of understanding the physics of our world and the representational powers of things digital. We don't imagine that what we have accomplished so far would excite most physicists. What we do believe that the DM path is now laid out. Those who are able to understand it are in for a good time.

Digital State and Informational Process

The Finite Nature assumption rules out the possible reality of infinitesimals, continuity, exact differentiability and infinities. All of these concepts would be relegated to the realm of providing good approximate models to physical processes. The truth or falseness of Finite Nature, will hopefully be settled by a simple and direct experiment. One expects that if Finite Nature is true, that we will have experimental data that determines the DM units of length and time in SI units.

Surprisingly, even without new experimental evidence as to the discreteness of space and time, we believe that a good understanding of *digital state and digital informational process* leads one to the conviction that there can be no physical reality to other kinds of state or other kinds of process. In other words, we are suggesting that we may already have enough experimental data to conclude that all of the most fundamental processes of physics must be digital. We are proposing that there is no reality possible for any other kinds of processes that purports to be exact models. We do note that some current mathematical models in physics and certain equivalent digital models can both exactly conserve such quantities as charge or angular momentum. In Digital Mechanics angular momentum and charge are conserved exactly just as they are in continuous mathematical models. Mathematical models that involve concepts of infinitesimals, continuity, exact differentiability and infinities will always be useful regardless of the truth or falseness of the Finite Nature Assumption. They are among the most important concepts of mathematics. We can construct wonderful and accurate theories with what we can imagine, but we can still deny the possibility of their exact reality. One might get a Ph.D. with a dissertation on the metabolism of a fire-breathing dragon but that won't let the author have one as a pet.

Continuous vs. Discrete

Most importantly is the great difference between the continuous mathematical models and the digital models: digital models can be set up on a computer and then they *evolve in time*. A digital model includes the representation of the state of the system, and the rules for its evolution in time, and the ability to bring the system into operation so that we can witness its evolution. A digital model involves a process. The analytic mathematical models of analog (continuous) processes do not *evolve in time*, they merely encapsulate knowledge about the relationships between numerical values, one of which is time, and they encode how to calculate one such value from others. Sometimes we have a mathematical formula that allows us to calculate a future state from a present state for an idealized, simple system. What we never get from a mathematical equation of physics is a derivable way to calculate the time evolution of a complex continuous system other than by converting it to a discrete system and modeling it on a computer. Newton mastered the 2-body problem in mathematical physics (e.g. an analytical solution for the motions of a star and one planet). He didn't find analytical solutions to the general 3-body problem and it still remains beyond our grasp; and what about the n-body problem? We now know that such systems are chaotic, disallowing the practical calculation of long-term behavior with equations parametric in time[9].

There is a simple relationship between systems that are *interesting* and those that are simple. An interesting system is one where its future state may surprise us. Simple systems, such as a Newtonian model of an idealized star with one planet or the motion of the hands on a clock do not produce any surprises. Mathematically we can say that when we have a straightforward solution, parametric in time, there are few surprises, it's not so interesting. When we can prove that there is no such solution then there is the opportunity for us to be surprised over and over again, and that possibility is what we find interesting.

All interesting things may be computed by any universal computer.[10] We will argue that the principal of Universality underlies all interesting phenomena.

It is true that there are such things as electronic analog computers. These devices are physical implementations of circuitry that can model the time evolution of variables constrained by mathematical formulae. The problem with analog computers is that they are clearly constrained to deal only with simple systems or with derived quantities such as pressure and temperature. Further they suffer from an inability to compute with high precision. While you could, in theory, solve any problem with an analog computer, you would find that the method of solution for complex problems would involve building a digital computer by using the components of an analog computer to make the parts of a digital computer.

A wind tunnel testing a model of an airplane is a kind of analog computer that is still useful in the world today. However so called *Computational Fluid Dynamics* continues to make progress at such a pace as to allow one to safely predict the time when wind tunnels will become obsolete.

A series of comments about how digital computation can model ever more complex systems doesn't mean much. What means a lot is the Law of Computation Universality.

The Universality Argument

The concept of Universality is extraordinarily important. It is a wonderous thing. We always like to think about limitations. How fast can a man run, how high can he jump, etc. The speed of light is a limitation as to how fast anything can go (with the exception of the Starship Enterprise). The charge on one electron is a limitation. There are all kinds of things that a computer can do so it is natural to ask two questions "What kinds of tasks can be done by a particular computer?" and "How complex does the machinery (processor) of a computer have to be?" In other words, given a design of a computer, we know that it can be characterized

[9] "Parametric in Time" means that we have a formula with time in it such as: d=s t; distance equals speed times time. If we travel at 60 kilometers per hour for 4 hours, the distance equals 240 kilometers. The number of computations to calculate the distance (one multiplication) is approximately the same independent of the amount of time. The number of computations needed for a computer model of some interesting phenomena is usually proportional to the time.

[10] Given that the computer has enough memory.

as to how fast it computes, but what about the range of complexity of the problems it can solve? A first guess might be that for any computer processor, there are problems that are just too complex for it to solve. Well, that's not how things work. Alan Turing, in the days before there were computers, came up with a concept that laid this question to rest. What he showed was that a clerk with a pencil, an eraser, a very long 1 dimensional paper tape, and a set of simple rules, could perform any kind of symbol processing task (in other words, could do anything that any computer can do). It might take him a long time but that's not the point. The point is that very simple machinery, with suitable instructions (a program), can do exactly the same things that any arbitrarily complex machinery can do. It just needs to also have as much available memory as the complex machinery.

The Laws of Programmability

Let us imagine some other place where the laws of physics are different. Imagine a 2 dimensional world called "Flatland".[11] Almost all the laws of our world would be different in Flatland. But what about the integers? What about Geometry? These could obviously remain the same. Sentient mathematicians who lived in flatland could make use of the same integers that we do, with the same arithmetic properties. They could extend the concept of geometry to 3 dimensions and discover such facts as the formulae that govern various 3-dimensional object such as cubes and spheres. Of course, there would be no reality to these 3-dimensional objects, but the Flatlanders could still imagine them, talk about them and know many facts about such hypothetical objects. Further, there is no reason to suppose that the flatlanders would have to do without computers. Strangely enough, if you ask "What resources must an alien physics provide in order to allow for the existence of Universal Computation?" The answer is simple; almost anything interesting will do! For example, we know that a Universal Computer can be constructed and operated in a 1-dimensional world. We know that almost all the law of physics could be changed without ruling out the possibility of Universal Computation. To rule out the possibility of Universal Computation you need a universe that meets one of 2 criteria.

It is so simple and dull that nothing interesting can ever happen.

It is so random and chaotic that nothing interesting can ever happen.

In all other cases the universe can almost certainly support Universal Computation. Since some conceptual universes are Computation Universal and others are not, you might wonder "How can we know, for a particular universe?" It is possible to prove that the Laws of a physics are Computation Universal. All you have to do is to show how you could construct a Universal Computer within those laws and you have proven that the underlying laws are Computation Universal. To prove that it is not Computation Universal can be very simple or nearly impossible. You must show that there is no way to construct a Universal Computer.

[11] Reference book on Flatland.

Thus we have defined a property of the most fundamental process any kind of physics, our physics or alien physics:

Is the fundamental process of the physics Computation Universal or is it not Computation Universal? The answer can be shown to be positive if we can build a universal computer. The experiment has been done and the results are in: The Fundamental Process of Physics is Computation Universal. This should be recognized as the **First Law of Physics**!

Before the computer age was upon us, there was no way for anyone to understand that the principle of Computation Universality had to apply to the absolute most basic process of physics. It is at the root of all of the complexity we see in the Universe. It is the basis of the possibility of Life, in all its possible manifestations. It is the underlying principle for the emergence of intelligence. And just as a lightning bolt is a manifestation of the kind of electrical charge found on the most fundamental particles, life and intelligence are manifestations of the fact that the most primitive and basic processes of physics are Computation Universal! Were those processes not Computational Universal, there could not be anything even as complicated as a general 3 body system interacting gravitationally. There could not be the kind of chemistry that we know. In short, there absolutely could be nothing whatsoever, in the entire universe, from most microscopic to intergalactic in size, that was in any way *interesting*!

Can Physics be richer than computation?

Why certain laws of mathematics and computation transcend physics!

What is it that can model a Universal Computer?

A process not programmable on a Universal Computer cannot be a part of physics.

A Definition of Magic

Magic means that we believe that there can be no precise explanation for how some process works. To make this clear, we need a definition of “precise explanation”. Imagine that we want an explanation for how arithmetic might be done. We might find one, in English, in an arithmetic primer. On the other hand, we could write a program that does arithmetic. The program is an objective precise explanation of how the computer does arithmetic. We can define “having a precise explanation” of some process as being able to write a computer program that does the process. When we are unable to write a computer program to perform some process, then we do not have an precise explanation for it. In that sense, we do not, today have an precise explanation for how factor 1,000 digit numbers in a reasonable amount of time.

There is another kind of explanation which we will call a “satisfactory explanation”. A satisfactory explanation is a convincing argument as to the eventual possibility of having a precise explanation. If we think that there can never be a computer program that factors 200 digit numbers, then factoring such a number would require magic. On the other hand, even though we do not today know how to write such a program, if we can explain, in principle, why we should be able to write such a program in the future, then we would have a satisfactory explanation and being able to factor 200 digit numbers would not be considered magic.

Assuming Finite Nature, physics is programmed on a Universal Computer! The proof of the Law of Programmability is then a tautology. If we do not assume Finite Nature but nevertheless do not allow magic in our physics, then the only shortcoming a computer has is one of size. In some sense, a Universal Computer can do every kind of informational processing that is not magic. If we have an explanation, that is tantamount to having a program. A good definition of "satisfactory explanation" with regard to some informational process is: "a satisfactory explanation is what is necessary and sufficient to allow one to write a program that causes a Universal Computer to perform an equivalent informational process." Finally, we can define "magic" as an attribute of a process for which we have no satisfactory explanation.

Today, there are many aspects of physics which fall into the category of magic, as we do not yet have satisfactory explanations. The law of programmability implies that eventually we will have satisfactory explanations for all physical phenomena.

It is possible to consider what is programmable on an infinite computer. For example, we could assume that physics deals with infinities, infinitesimals and continuity. Could an infinite computer (infinitely large and perhaps infinitely fast) be able to exactly emulate our physics? This is a good question but unfortunately it will not be further explored in this book.

Arguments In Favor of Finite Nature

"Finite Nature" is the name we give to the assumption that all quantities of physics are finite and discrete. A quantity is discrete if the amount of the quantity can always be exactly described by an integer. What seems a certainty is that space-time must be, ultimately, continuous or discrete. We know many properties of nature, such as matter, charge and angular momentum that are finite and discrete. The number of atoms in any quantity of matter is always an integer. Further, we are not persuaded by any argument we know of as to the necessity of the ultimate continuity of any quantity in physics. We cannot even imagine any practical experiment that might determine that a quantity of physics was continuous in the mathematical sense. In addition, the same point can be made for differentiability, infinities and infinitesimals. We can understand the ideas about such things, but it is unlikely that we will ever be able to do more than rule out discreteness at some level.

As we shall explain, if space-time is discrete, then all quantities of physics must be discrete. For now, all we can say on the basis of direct experiment is that the Finite Nature hypothesis is in limbo; even as to an upper bound for the length of the unit of length.

Many people would like to ascribe to the space of physics, properties found in Geometry such as the properties of a line or a point. Indeed, we are often told "…the electron is a point particle." We shall see from the Digital Perspective that this concept is an informational impossibility.

The most amusing argument as to the belief in physical continuity has to do with the marvelous success of the calculus. It is argued by some that the success and the enormous breadth of application of the calculus somehow implies that space, time, and other attributes of physics must involve continuity. This argument cannot be taken seriously. The Calculus is just too good! It beautifully models all kinds systems that are discrete. We happily apply the calculus to systems where we measure pressure, radioactive decay, electrical currents, mass flow, sound waves, etc. and we get nice, approximate answers, despite our approximating discrete processes and discrete quantities with continuous mathematical models. So, if the calculus is excellent at modeling continuous systems and excellent at modeling continuous approximations to discrete systems, what does that say about that which is well modeled by the calculus? It says that being well modeled by the calculus offers little support for either hypothesis: continuous or discrete.

Every so often, as a result of analyzing the data from some experiment, there is a published result that if some physical quantity is discrete it must be discrete below some experimentally determined level. These kinds of arguments are certainly correct for some kinds of models of discrete processes. However to our knowledge, they are universally wrong when it comes to the kinds of models that we call Digital Mechanics[12]. While the appropriate length scale for a DM model might be around Planck's Length[13], it seems much more likely that the length scale might be closer a fermi[14]. We will come back to this last astounding possibility after we have explained what DM is and how it works.

The Finite Nature Assumption is:

At some scale, space and time and all other quantities of physics are discrete.

The number of possible states of every finite volume of space-time is finite.

Every physical constant (and every other basic quantity of physics) must be an integer, or must be able to be exactly represented by an integer.

The Digital Perspective requires that our use of the word "finite" implies that there can be no locally determined true randomness.

The state of a physical system may be thought of as filled with Bits and groups of

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[12] This is explained further in SectionYYY

[13] Planck's Length, 1.61605 x 10^{-35} meter, is a length that can be simply calculated from fundamental constants: the speed of light, c; the gravitational constant, G; and Planck's constant ∇. We do not know whether Plank's length actually has any physical significance.

Planck's length is calculated as follow: $\sqrt{\frac{\eta G}{c^3}}$

[14] A fermi is a measure of length that is about the *size* of a nucleon (a proton or a neutron), 10^{-15} meters. A millionth of a millionth of a millimeter. It is named after Enrico Fermi, a famous physicist.

Bits that have meanings. We know this because we know that computers can use bits to exactly represent the meanings associated with any finite (discrete) set of states. A computer can exactly model any finite discrete system as envisioned herein. We believe there is no such thing as a finite discrete system whose meanings cannot be exactly represented by the state of a digital informational process, such as by the bits in the memory of some kind of computer-like system.

The evolution of a physical system, given Finite Nature, may be thought of as a consequence of a computation that changes the meanings of bits by changing the bits or by changing the locations of the Bits. We know this because of the fact that the definition of the workings of physics (given the Finite Nature Assumption) must be isomorphic to the workings of some Universal Computer. What we claim is that there is no such thing as a finite discrete process that cannot be exactly modeled by a digital informational process.

For example, if there is a volume of space-time (assuming Finite Nature) that has an electron in it, then there are bits in that volume that carry the meaning of the concept specified by the word “electron”. Further, the velocity of the electron is also specified by some interpretation of Bits in that approximate volume. The Informational Process of the cellular space processes the meaning of the bits that represent velocity in a way that results in the electron moving through the space with that velocity. Finally, if the electron is accelerated by a field or by interaction with a photon, then the bits that represent its momentum are changed as the momentum changes. In other words, rectilinear motion and acceleration are consequences of computational processes. There are bits that tell the process what the motion should be, and the process obediently moves the particle with the proper motion while carrying along all the Bits that have relevant information. Acceleration involves a process that changes the bits that correspond to the velocity.

There are an obvious number of areas where what we have just described seems to violate a number of Laws of Physics. That is true for some of the laws that are stated as natural language statements. We believe that that is not the case for laws that are expressed as mathematical formulae and we intend to explain why. The Digital Perspective is not a simple substitution of Difference Equations using integers instead of Differential Equations. It is a concept alien to common mathematical thinking. However, as we explain one aspect after another, it will become apparent that it is possible for the world to be well modeled by some version of DM. Many of the gut reactions to dismiss DM without a good look are related to a lack of in depth familiarity with things Digital.

Why Cellular Automata

In the mid 1950’s the idea of DM began to jell. The concept of the Universal Computer, as candidate for underlying engine of physics, was clear. However, the first models were very primitive and had gaping inconsistencies with physics. (More gaping than today!) For a short time, DM took form as a computer simulation of Particles and their Interactions (PIDM). Gravity and Relativity posed no problem for such models, because such a program could incorporate any and all mathematical laws of physics. But PIDM had insurmountable flaws; it did not deal with questions such as "…why the particular particles and why all the numbers?" Instead, the particle interaction model simply takes as part of the model, all of the numbers and all of the facts we know about physics and the particles. In such models, there is a chance of the discovery of emergent behavior that is not *put* into the model. In fact, all current computer simulations done in physics are similar to PIDM, the only difference being one of scope. PIDM requires that the model incorporate all of physics. It might do a fair job of simulating physics, but it doesn't really tell us anything about why things we had to determine or measure experimentally are as they are. Finally, all PIDM models are just too ad hoc.

But after a very short time, the conceptual framework was transferred to Cellular Automata (CA). This concept is usually credited to Stan Ulam and Johnny Von Neumann. Actually others[15] had thought of the cellular automata idea earlier, but none thought to demonstrate that such a system could be computation universal. Even with CA there were enormous problems, but there were 3 winning features.

1. The locality of the CA space corresponds with the locality of physics.
2. Von Neumann had shown that a CA could be Computation Universal.
3. CA's were wonderful at producing emergent behavior.

We soon became convinced that the CA model was the most promising. Modern DM started in 1960 by creating simple rules for CA systems and programming computers to run those rules. In the mid 70's, the MIT group working on DM discovered that Konrad Zuse had written a book (in German) about a cellular automata model of physics. We had the book translated into English and invited Zuse to come to MIT to meet with the group. He came and it was a wonderful visit. He told how the publication of the book had caused him to be thought of as a crackpot. No one whatsoever had taken him seriously until we got in touch with him. Of course, no one in the physics community has taken DM seriously even up to the end of the millennium, a quarter century after Zuse's visit to MIT.

If there is a CA model of Physics, how will we know whether it is the right model? What one universal system can do, any Universal system can do. This means that if an exact DM model of Physics is found, that there will be many exact models. The only two criteria that might cause us to pick one over another are economy and esthetics. We can use Occam's Razor to winnow the field. The most important test of a proper CA model is that it should only require the 7 constants of the DM theory, with all the rest of physics being emergent. We can refer to all such models as Effective DM models. Once an Effective DM model is found, there is no limit to the number of other, distinct Effective DM models. However there is a way to order them all. This has to do with two criteria: the informational complexity of the definition of the model and the informational efficiency of the operation of the model. The efficiency of the operation is

[15] The late Harvard and MIT Professor, Henry Stommel, had told me about a cellular automata model of sand dune behavior that was done in the 1930's.

proportional to the ratio of the space-time volume that can be emulated by a given cell-state volume. The best valuations in terms of these two criteria may or may not both occur in the same DM model.

There is an interesting question re the characteristics of the CA underlying DM. "What do the laws of physics have to do with the operational properties of the basic engine that runs the CA models used in DM?" The answer is very simple and somewhat surprising. "Absolutely Nothing!" The informational process that is a result of the operation of the CA engine is what produces the process we call physics. The engine and the laws governing the attributes of the engine itself are outside of physics, outside of this Universe. There is no need to suppose that the laws of our physics pose any constraints on the engine whatsoever. When a computer is running a simulation of some silicon based microchip, does it matter whether the chips in the computer are made of Silicon or Gallium Arsenide?

The Octahedral Particle

The Octahedral Particle is a design exercise that was done in the 1980's to illustrate how the characteristics of a regular RUCA substrate could efficiently represent some of the attributes of a particle. In particular, the idea was to have a model for informational representations of momentum and force while being very efficient in the representation of that information. The Octahedral Particle is a concept that illustrates a principal; it is not meant to be realistic. Within a number of RUCA systems there exist structures called "shuttle trains". These are like trains that travel in a straight line along a coordinate axis, and that can be turned or reflected by various structures. We further know from Fredkin and Banks[16] that one can do digital logic in the simplest of RUCAs. Therefore, the idea of a serial adder that can add a binary value of a number encoded in a shuttle train to another binary number, seems like a reasonable process that could be implemented in a simple RUCA.

From a simple minded perspective, the most efficient representation of a magnitude in a CA would be as a binary number. Thus, the x, y, z momentum components of a particle could be represented by 3 binary numbers. There needs to be a process that moves the particle through space with a velocity proportional to the momentum information. Finally, there needs to be a kind of photon particle that can change the momentum of the massive particle. This particular model has particles, but no waves!

What we will describe, in an informal manner, is a structure and process that might be possible in some kind of simple RUCA. We will not worry about the details of the rule, or even the specification of the neighborhood or the number of states per RUCA cell, except to say that we imagine a small number of states: 2, 3 or 4.

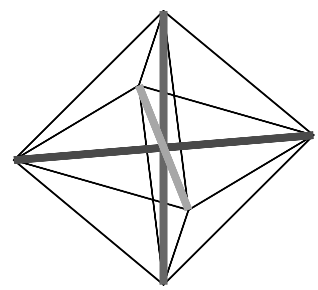
We start with a semi-stable structure which is a thin shell which is shaped like an octahedron. The 6 corners of the octahedron are aligned so that opposite corners

[16] Roger Banks, MIT Thesis & others

in the x direction have the same y and z coordinates, opposite corners in the y direction have the same x and z coordinates, etc.

We imagine that within the octahedron there are three binary numbers, each lying along a coordinate axis that connects one corner to the opposite corner. These 3 numbers represent the x, y, and z micro-position. In addition, there are the 3 momentum shuttle trains, each of which are in orbit, moving back and forth from one corner to the opposite corner.

The red, blue and green lines represent the areas where the 3 sets of shuttle-trains orbit, back and forth.



The concept is that the numbers in the 3 momentum shuttle-trains are to be added, respectively, to the 3 corresponding numbers that represent the micro-position. There are a number of ways of doing this. We suggest that the addition be a serial process that involves the movement of the 2 numbers past a structure that will add them together.

Eventually, the bit structure that represents a particular micro-position (such as the x micro-position) has a major carry from the most significant bit that makes the structure one bit longer than the distance from that corner to the opposite corner. In a sense, that carry pops out of the end of the structure. The carry starts a wave that proceeds from that corner, down the edges and faces of the entire octahedron until the wave terminates at the opposite corner. The consequence of that wave is that the entire octahedron and its contents has moved one step in the direction of the major carry bit (which is lost in the process). So, the value of the micro-position variable is treated modulo 2^n where n is the length, in bits, of the Octahedron, corner to opposite corner.

The overall design is such that any shuttle inside the octahedron that encounters a face or an edge, is forced to turn to follow that face, or further to turn to follow that edge until it comes to a corner. At the corner, it reverses direction to head for the opposite corner. This has the effect that when the octahedron moves over one bit in x position, the y and the z shuttles automatically realign themselves so as to still be traveling corner to corner.

The point of all this is that the particle described is, in effect, a little machine, built out of bits in a RUCA that has a rule, simple yet supportive of the properties necessary to allow the described behavior.

A photon is a similar machine. The speed of a photon has nothing to do with the magnitudes of the 3 momentum information, however the direction of the photon is determined by them. This could be accomplished, in a kludgey fashion by having 3 shuttles for its direction of travel, another 3 for micro-position and a final three for the momentum vectors. When a photon collides with a particle, the following sequence of events happens. We will assume that some part of the photon structure collides with the particle structure. The result is that the wall between the photon structure and the particle becomes transparent to the shuttle-trains of the photon that represent its momentum. They escape from the interior of the photon into the interior of the particle. Each proceeds in a straight line until it encounters a wall or edge. Then using the same mechanism that keeps shuttle-trains centered on the appropriate coordinate axes, they each find their way to the proper corner (on the basis of their initial direction of travel) and when the run into the momentum shuttle train their binary value is added to that of the corresponding (x, y, or z) momentum shuttle train. This is how the momentum information of a photon is added or subtracted from the momentum information of the particle. There are 3 cases: a photon of light (added), a photon of charge interaction for unlike charges (subtracted), a photon for like charges (added).

Topics

Computers are physical objects

Universality and Interesting are tautological equivalents

Physicist think that conservation laws come from symmetries

The reverse notion is that the absolute conservation laws imply the necessity of symmetries

The main point that may get lost is that its ordinary computation is part of physics "Semi-Classical Model of Physics"????????????????????????

Ackerman function.

We know a fair amount about the ideas of infinities and infinitesimals, about continuity and differentiability, about real and transcendental numbers. But we do not know of a single example from the real world where there is compelling evidence that supports the possible reality of any of these concepts. Let us consider the geometric concept of a point. It can be defined as the intersection of 2 lines. However, what arguments support the notion that we can draw a real, geometrically correct line or define a real point with the properties that geometry demands? What argument supports the contention that reality allows the numbers of points and lines that geometry makes possible?

Up until now, the answer could best be framed as "Why not?" There was no reason to reject infinities and infinitesimals, continuity, and the attribution to physical space of properties of geometry. On the positive side there was the wondrous success of the calculus as applied to physics. Just consider the formulae of electrical engineering where we happily take the derivative of a changing electrical current represented by the letter "I". The reality of a varying electrical current is vastly more complex, involving discrete electrons and discrete atoms and enormous complexity; all hidden and wondrously represented dI/dt. In truth, DM cannot diminish the power, efficiency and beauty of the Calculus. In the world of geometry, the calculus gives good answers based on a correct model that assumes continuity. If DM is a good model of physics, it only adds to the wonder of the calculus; the calculus gives good answers in physics despite being based on an approximate model.

Our understanding of computation leads us to believe that computation is a resource subject to some kinds of physical laws. What this means is that a certain amount of computation must require a certain volume of space-time and/or mass-energy. We assume that the Universe is finite in volume and mass-energy. Even more compelling is that in a small amount of laboratory resources, a space-time volume of 1 cubic meter second and mass-energy of 1 kilo, we have good reason to assume that there is only a limited amount of possible computation. It may be a lot of computation but still a finite amount of computation.

We often describe the amount of time a computation takes as polynomial or as exponential. This can be explained by a couple of examples. If we wish to add up three numbers (the addends), there are a many ways to get the sum. A very simple way is to start 2 counters at zero. We then make both counters increase by one until the first counter equals the first addend. We then reset the first counter to zero and then increment both counters until the first counter is equal to the second addend. The process is repeated for the third addend and when done, the sum of the three addends is in the second counter. Another method involves adding up all the least significant digits, producing a sum digit and a carry digit and then repeating this process for the successive digits (along with the prior carry digit) for however many digits there are in the largest addend. The amount of time taken by the first method is called “exponential” because if there are a total n decimal digits, the total time would be approximately 10^n steps. There is no way to represent 10^n by a polynomial. The second method involves between one and two steps for each digit (more than one because of the carry digits) so the time can expressed as a polynomial, in this place it’s linear. Given a big enough problem any exponential task will take longer than a polynomial task.

In QM, we have methods of modeling systems where the computational complexities are exponentially related to the number of particles. Does it also make sense to imagine that fundamental physics might pose computational problems that are exponentially related to the space-time volume? What does make sense is that there are computational algorithms that take exponential time to solve problems that can also be done in polynomial time. It has nothing to say about any particular algorithm. Given any algorithm that takes polynomial time, there are always other algorithms that compute the same function while taking exponential time. What seems to be true is that for the kinds of problems that we calculate using the rules of Quantum Mechanics, the exponential time algorithms are much better than certain polynomial or even a linear ones! That is because physicists are trying to solve problems involving a few particles, while physics is finding the solution for a space-time volume!

Thus there is nothing compelling about concepts in physics, such as in QM or in QCD, that today, seem to be computationally difficult or even intractable. There is a very human tendency to elevate our inability to solve some problem to the level of declaring that a law of nature prohibits finding a solution.

When we imagine some microscopic process of physics that is equivalent to an infinite amount of computation, then something is clearly wrong. Computation done by any method needs resources, such as space, time and energy. If some natural process is doing an infinite amount of computation, it must be using an infinite amount of whatever resources are necessary. This little analysis suggests that no microscopic process of physics is equivalent to an infinite amount of computation.

What we know about computation is that while some computers are faster than others, there are no general shortcuts to solving computational problems. Certainly there are no general shortcuts to reduce an infinite amount of computation to a finite amount. It is reasonable to conclude that space-time, mass-energy and the laws of physics can all get together to compute. What they can't do is get together to do magic. We can imagine that one kind of computer can do, in polynomial time (with regard to the size of the input data), what another kind of computer would require exponential time to do. It is hard to imagine a physical computer that can do things in finite time that <u>require</u> infinite time on ordinary computers. From the perspective of computation and its equivalents, what many people currently believe is true of physics must involve magical processes. The magic steps almost always boil down to two implicit assumptions: first, that it's ok to demand the equivalent of an infinite amount of computation from finite resources and second, that a process that is informationally impossible without access to certain information can do just fine without access to that information.

And what is the point? Occam's Razor needs be called upon to referee between two models: The first (Imagining physics can operate exactly according to current mathematical models) involves physics needing infinite resources, infinite computation, infinite numbers of infinitesimal quantities, the ability to do magic and one saving grace; there are often, but not always, succinct mathematical models that are good approximations. If you want to boggle your mind, imagine the computational load implied by the many-worlds models of physics. The second model (Digital Mechanics or other future digital models of physics) might accomplish the same with finite resources, finite computation, finite numbers of finite quantities, no magic and the same saving grace; there are succinct mathematical models that are good approximations. If we discover that Finite Nature is the correct model of the world, the mathematics of physics won't suddenly become inoperative. The only difference would be to invalidate our current assumption that the mathematical models are true and exact descriptions of nature. What would not be invalidated would be the fact that the current mathematics of physics gives the right answers. Many mathematical models would be asymptotically correct. Occasionally the mathematical models would merely be good approximations. And of course, other mathematical models are exactly correct independent of whether or not *Finite Nature* is true or false. For example, in DM and in ordinarly physics, momentum is exactly conserved.

Representing Information with Bits

DM has the property that at the most fundamental level; one can understand everything in its entirety. Not just understand everything, but understand all the basic phenomena exactly. No magic whatsoever. Nothing more underneath. This is a counterintuitive concept that one needs to digest before it makes sense. When we build a computer, we use various two state physical systems to represent bits. In the Random Access memory, it is usually the electrical charge in a capacitor. On a disk drive, it is the orientation of the flux in a magnetic domain. On a CD it may be a distortion of the surface that can be sensed optically. Whatever it is doesn't matter insofar as the informational process is concerned. In this paper, whenever we use the word "computer" we mean just a processor and a memory. We are not normally, in this paper, concerned with all the other things, such as displays and keyboards that are part of normal computer systems. We always assume that whatever the computer is to process is already in the memory and that the results of the computation are also left in the memory.

While there are many ways to use the physical properties of matter and energy to represent bits, bits can also be represented by bits! This can be done by starting with a program, running on computer *A* that does physics using electrostatic charges to represent bits in memory. Next, another computer, *B*, can simulate *A*. While B uses electrostatic charges directly to represent bits in memory, the simulated version of *A* no longer uses electrostatic charges directly to represent the bits; it uses the bits in B to represent the bits in A! This is not a cheap trick but rather a profound point. We propose that digital information is at the bottom of physics. We need not look further or ask how that information is represented; the representation is not a part of this universe and definitely not subject to the laws of physics. While a computational model might be able represent physics, there is no doubt whatsoever that computational models are more general than our physics in terms of what it takes to support the ability to compute; a computational model does not need to be hosted in a place that has our laws of physics.

We know a lot of practical facts about bits. We know how to transmit them from one place to another and how to store them for a long time without any spoilage. It seems that we can make bits and destroy bits, but not everything is as it seems. What we need to understand is that there are the practical kinds of bits used in engineering and commerce and then there are bits that correspond to various theoretical models. From electrical engineering (communication theory) we understand that the word "bit" is used to convey two different meanings:

The Shannon Bit: a measure of an amount of information. A system where there is an ensemble of n equally probably states means that the system can represent Log_2 (n) Shannon Bits. Aside from this very paragraph and a few references to the “Shannon Bit”, information that is not digital is not a topic in any way related to anything in this paper.

The Binary Digit Bit: a two state system that is a single binary digit, where a system with b such bits can represent at most a total of 2^b states. This is the Bit of the DM Theory.

To avoid confusion, when we use the word “bit” without the name “Shannon” preceding it we will always mean “The Binary Digit Bit”. Of course, we know that n bits can represent up to 2^n different states.

Very often, what we have to say about bits is also true about digits in general. Anything that can be done with 2 state logic can also be done with digits that are decimal (10 state), octal (8 state), ternary (3 state), bytes (256 state) or digits to any other base. When we use the word “bit” we are referring to a 2 state digit but we usually mean to imply that it could be any other kind of digit.

It is often very difficult to measure the amount of Shannon Information given a collection of bits. The problem is that the amount of information is not proportional to the number of bits, but rather is proportional to the log of the number of meaningful states that the bits might be in. In some contexts we need to consider the probability of each of the possible states. We mentioned earlier that 7 bits would be sufficient to label each atom in the Universe as to its atomic number (assuming no more than 128 different atomic numbers. While 7 is sufficient, is it necessary? If we assign the bit string “1” to Hydrogen and “01” to Helium and “00 XXXXXXX ” to Lithium and all the rest, then while most of the different kinds of atoms would need 9 bits, the average number of bits per atom can be reduced to approximately 2 bits per atom. This is because most atoms in the Universe are Hydrogen (1 bit) and a large proportion of the rest are Helium (2 bits).

(Trying to measure the amount of information in a bunch of bits makes no sense at all unless the bits are part of some system, wherein at different times, places or circumstances, the bits take on different values associated with different meanings. Thus the measure of information cannot be a property of a isolated collection of static, meaningless bits, such as represented by the arrangement of atoms in a rock. The bits must be associated with a process where at different times, places or circumstances, the bits have or could have meanings and different values.

If you consider a computer[17] with a very small memory constantly running, then eventually the computer will find itself in a state identical to some previous state. A good measure of the informational content of the memory (of the running process) is the $Log_2(k)$ where k is the number of distinct and different states the memory actually takes as opposed to what it might have taken. k is also equal to

[17] See the definition of “computer” on page XXX

the number of steps until the computer completes a cycle. When thinking about theoretical models of computation, it's best to leave out the idea of a halt instruction. There is a quaint and antique concept, which is a part of the literature on Turing Machines from half a century ago, that all computers halt when they get to the answer. Since a computer is a finite machine, eventually it gets back into some prior state. From that point on it is in a cycle. The cycle could be just 2 instructions long, taking a fraction of a microsecond, or it could be long enough (theoretically) to outlast the universe.

Thus, the Digital Perspective tells us that the measure of information is only defined for systems that in one way or another involve a process. Even then, the bits must have meanings. It also shows us that we can use bits to represent all quantities and qualities. We have discovered that there are many ways to use and interpret bits so that they have meanings. Finally, we understand that there are ways to look at the meanings of bits and using algorithms, change the meanings of some or any of the bits.

Basically, computers are built out of wires and gates. We call it Digital Logic. A gate is a kind of computer switch usually made of transistors. From the model of reversible digital logic called Conservative Logic, we learn that whatever can be computed, can be computed by a computer built only out of Conservative Logic gates. In conservative logic, both information and the bits are conserved. For both logic states (usually 1 and 0) neither a 1 nor a 0 can be created or destroyed. Further, all well formed Conservative Logic circuits are reversible. This means that the process does not destroy or create any information. This turns out to pose no kind of handicap to the computation in terms of speed or efficiency.

And then there is the wonderful and glorious property of *Universality*. This is a property true of every commercial computer; no matter how humble. It's a fantastic idea and a magnificent characteristic. Imagine, any old computer (a processor and memory) can do absolutely everything that any other computer can do (again just the processor and memory), no matter how new or expensive! All you need to do to make that statement true is to give the old computer access to a memory basically just as large as the memory of the computer it is going to emulate. The only caveat is that it most likely will take a lot longer to do the task, but that aside, it always can do it exactly and perfectly. This is what every computer can do. It's so simple it makes one who finally gets the whole picture, want to laugh or cry.

With only these few concepts, we can understand the most basic and important aspects of computational processes and with a little more effort one can learn enough to understand it all *exactly*; no approximations, no generalizations, no simplifications. All computer engineers can understand the workings of a straightforward Universal Computer perfectly and exactly. This is true despite the fact that such a computer, if built, might contain thousands or even millions of transistors acting as gates. All this and no one can understand the workings of even one real physical transistor exactly.

To appreciate these conclusions you must realize that there is a model of computation called Automata Theory. The level of understanding of both Automata Theory and computers, from the Digital Perspective, is at the bit level. We don't care about voltages, magnetic domains, electrical currents or other physical properties that represent bits. Though important to computer designers, they are totally irrelevant to the Digital Perspective. We not only don't care, but we consider the fact that we don't need to care to be the epitome of all our beliefs about the Digital Perspective.

The Laws of Bits

Combine with the previous computer stuff!

The emergence of computer technology has introduced us to the concept of informational processes. An informational process evolves over time according to certain laws. At any given time, a computer is in one of a finite number of states. The main law is that there is a single functional relationship that relates each state of the computer to the next state. That function is known as the *design* of the computer. Everything that happens is a simple, logical consequence of the design and the state. What is interesting is that there is almost no science of computation (as there is a science of physics) but there is one amazing proof owed to Turing that was actually dates from the days before computers. The proof is of the existence of Universal Computers that can essentially do anything that any other computer can do.

In books and papers about Automata Theory, a Universal Computer is defined as having an infinite memory. That may be nice for mathematicians, but us physicists and engineers will be happier with the definition involving finite memory. The principal is that the universal computer must have just slightly more memory than the computer it is to simulate. The little bit of added memory is to contain the simulation program. The rest of the memory is used to simulate the memory of the target computer.

The *computer* in Turing's paper was a clerk with a pencil, eraser and a long strip of paper tape. One can prove that a particular computer is universal by demonstrating the design (by writing a program) of a simulator wherein that computer can simulate some other universal computer. If you can write a program for computer A, which simulates the operation of computer B (where B is a Universal Computer that contains slightly less memory than A) then A is Computation Universal. Every commercial computer (such as a PC) is Computation Universal. To simulate a computer B with M_B bytes of memory requires a machine with just a little bit more than M_B bytes of memory. The reason is that you need a small number of bytes for the simulation program, and the rest to represent the information in the memory of B. The inventors of

Automata Theory, who first worked on such ideas, had a fixation with machines with infinite memories. The concept of *Universal Computer* also makes perfect sense as defined for machines with large but finite memories (ordinary computers).

Most of what computer engineers (designers and programmers) do is art rather than science (with regard to computation as opposed to solid-state physics or electrical engineering). We practitioners of that art have learned a number of things not yet memorialized into Laws. For example, when a computer company floated stock onto an unsuspecting public on the basis of claiming to have a compression algorithm that compressed absolutely all computer files into 1/2 the amount of memory, and then could decompress those files to recover the exact original version, experienced practitioners in the computer field knew the claim was nonsense. That fact did not stop the company from deluding the investors. The company spokesperson said "… if you need further compression, (such as to 1/4 the amount of memory) you can just run the algorithm twice!" The reason the claim was nonsense had to do with the words "…absolutely all…" A simple example will suffice to explain why. One 8-bit byte can represent 256 different things. Four bits (1/2 a byte) can represent only 16 different things. A decompression algorithm working on the four bit compressed bytes could never generate more than 16 different kinds of eight bit bytes. Having extra information around that enables it to handle the same 4 bit quantities differently at different times is a form of cheating because then the 8 bit byte was not compressed into 4 bits, but perhaps compressed into 4 bits plus another 5 bits to tell it what to do with the 4 bits, for a total of 9 bits!

A mediocre law of compression could be stated as follows: The best a loss-less[18] compression algorithm can do, given a subset drawn from an ensemble of equally probable tokens of equal length files to compress, is to compress such files into a number of bits equal to $Log_2(E)$, where E is the number of possible different files in the ensemble from which they are drawn. It's not as neat as Newton's laws, or the law of conservation of momentum.

‘t Hooft, Factoring and Discrete Physics

During a recent discussion[19], Gerard ‘t Hooft suggested to me the following idea: A polynomial time solution to the problem of factoring large numbers is a point in favor of the possibility of a discrete and deterministic process underlying QM. Using Peter Shorr’s algorithm, a QM process is, in theory, capable of providing a polynomial time solution to the factoring problem. At the present time, the best discrete, deterministic approach (using an ordinary computer to calculate the

[18] A loss-less compression algorithm allows for the exact reconstruction of what was compressed. E.g. PKZip will compress most computer programs which must be restored exactly when unzipped. MPEG, JPEG and MP3 are algorithms that compress movies, pictures and music respectively, by means of clever algorithms that throw away hopefully unimportant data. Such a file cannot be uncompressed exactly, only uncompressed approximately.

[19] Antibes, France, 11th to 14th of August, 2000

factors) is exponentially difficult. If one could prove that a computer program to factor large numbers must be exponentially difficult in the size of the number, that erodes support to the concept that a mechanistic underpinning to QM might be possible. Finding a polynomial solution to the problem of factoring large numbers with a computer or proving it exponentially difficult may well be an important problem in theoretical physics.

Purpose of a Computational Process

The purpose of a Computational Process is to cause the temporal evolution of the meanings associated with the values of integers in the memory of the computer. This is accomplished by a process that changes the bits in the memory of the computer to reflect the desired changes in meanings.

Universes Capable of Hosting Computation (To be continued)

Some laws of physics are different from other laws of physics. We see, in experiment after experiment that whenever we have the opportunity to measure the total momentum of all the participants in some event, that the total momentum remains the same despite changes in the individual momenta of the participants. This is a positive fact. It is not that we cannot measure momentum and thus have no reason to believe that it might change. It is something that we can measure, we do measure it and we observe that the law is universal as far as we have seen. Despite the fact that we believe in many laws of physics, physicists are continually interested in testing the various laws, CPT invariance, Conservation of Lepton Numbers, conservation of hadronic flavors, etc.

On the other hand, there are things that we have searched for and not found, such as magnetic monopoles, neutrolinos, charginos, gluinos, etc. We once wondered about the possible compositeness of baryons and mesons. Now we believe that we know the answer, "Yes". QCD is such a good model as to convince us all. We can still harbor the suspicion that quarks and leptons might also be composite. The answer could go either way and even go one way and then another, as the line of accepted theories of physics wanders through some kind of knowledge space.

But the lord and master of our knowledge of the world is not our theories and models. It is the results of verifiable experiments. Of course, early experiments often produce unsure, inaccurate and unreliable results, but we cannot reject well-founded, reproducible experimental evidence just because we don't like it. Many scientists had trouble accepting the reported results of the Fedyakin-Derjaguin experiments on Polywater back in 1962, but by 1973, Derjaguin laid it all to rest as a false alarm. Most physicists couldn't accept the results of the Pons-Fleischman Cold-Fusion experiments. While a fringe continues the efforts, our concepts of physics have not undergone any consequent change because there is not yet any scientifically reproducible result. In 1887, most physicists simply didn't want to accept the consequences of the Michelson-Morley experiments attempting to measure the speed of our drift through the ether. However, in that case, the experiment was well done, the results were reproducible and it was our conception of the world that had to change whether we liked it or not.

The Meaning of "Meaning"

Finite Nature allows us to give a simple and rigorous definition of the words "mean" and "meaning" with regard to physics. "Meaning" is a property of an informational construct, e.g. an English Language word, a datum in a computer register or a configuration of states associated with a single elemental particle. In every such case, there is a purpose for the information. This purpose is to cause a particular time evolution of that or other information. When we say "cause" we mean that if the information were different then so would the time evolution. This time evolution may simply involve the persistence of something, its motion, its transformation or, in the case of more than one thing, their interaction. A many to one relationship can exist between different informational constructs that are associated with a given purpose, despite the fact that the underlying process is microscopically reversible.

The meaning of the information has to do with the ways it will affect the informational processes that interpret it. For example, consider a 32 bit floating point number that represents the temperature (Celsius) of the processor chip in a computer. A rule might be that the processor must be shut down if the temperature exceeds 200° Fahrenheit. The algorithm in the computer reads the temperature, converts the number to Fahrenheit by dividing by 5, multiplying by 9 and then by adding 32. It then tests to see that the resulting number is less than 200 and if so, the computer continues in operation. The meaning of the word that contains the temperature is that it represents in degrees Celsius how hot the processor is, with respect to whether or not the processor should continue in operation.

We must imagine a system where a *Digital Informational Process* can examine the state of something (we will imagine that the *something* is a particle). From that state, the *process* is able to calculate a higher level property of the particle. For example, consider a particle constrained to move in only the x direction. It has an x velocity. We must assume that somehow, in the particle or in the space around the particle, there is some kind of representation of that velocity. Otherwise Zeno's Paradox of the Arrow in Flight would argue that the particle would, from one instant to another, take any velocity. Further, by continually examining **************(to be continued)

Computation Universal

What does "Computation Universal" mean? We use a more modern view of the concept, taken from Automata Theory. The classical "Universal Machine" is defined in Automata Theory as having an infinite memory. All else are called "Finite State Automata". This viewpoint is, today, a bit of pedantic excess. Every modern computer would be Computation Universal in the old sense if it merely was connected to an infinitely long tape. The modern meaning of Computation Universal means that such a computer can exactly emulate what any other computer (Universal or not) can do, given that it has slightly more memory than the other computer. The *slightly more memory* is the memory needed by the emulation program, the rest of memory represents the information in the memory of the computer being emulated. Thus, any such universal computer, such as an IBM PC, can exactly emulate the behavior of any other computer. There are 2 caveats: first, it needs enough memory, and second, the emulation may run faster or slower than the target machine. It might run very, very much slower!

Once we subscribe to the first 2 laws, the third law is obvious because we know we can build universal computers.

The *correct* RUCA law is a matter of economy and esthetics.

The Cost of Conserving Bits

What is a Cellular Automata?

Achieving RUCA Reversibility

We have a tool kit at our disposal that we can use to easily achieve reversibility. The first is the simple use of a second order system. Whenever we create a UCA as a second order system, where both the past state and the present state are both explicitly there, there is a trivial method for achieving Reversibility. It relies on computing a function of the present state, and using it to change the past state (into becoming the future state). Then we re-label what was the present as the past, and the future as the present, and repeat the process. The only requirement for this process to be perfectly reversible is that for every possible function that changes the past into the future, there must be an inverse of that function. As examples, all permutations of elements in the past have such an inverse, as does the operation of integer addition where the present is added to (or subtracted from) the past. If the quantities in the cells are conserved (which makes lots of sense for other reasons) then whatever function is performed on the past, it is always a permutation.

Thus, given 2 conditions, second order and conservation of bits, along with some kind of automata like rule, reversibility emerges as a property of the system, without any explicit effort.

There is also the *Transform*, that can take systems of differential equations used to model phenomena in physics, and convert them into exactly reversible algorithms, without changing the basic characteristics of the computation. The deviation between a normal algorithm and a reversible one is generally of the same order of magnitude that would result from doing the computation on another computer with a different word length; such as switching from a 64 bit word to a 63 bit word. Obviously any difference between two algorithms can drastically affect the final results of a system that becomes chaotic. Finally, any model of a system that finally decays into a particular state and then remains exactly in that state, cannot be modeled by a reversible system. In any case, all such systems are approximations and are not physically correct. No physical system can decay into a final state and remain there because that would violate a law of nature: the fundamental, microscopic laws of physics are reversible (with CPT). Thus any model that becomes stable is, at best, an approximation.

Achieving RUCA Universality

“Universality is interesting.” The previous sentence is a tautology. All universal systems have the capability of being interesting, and it seems clear that a system that is not Universal, is in some sense always uninteresting. This needs some further explanation. What we mean by “system”, is something that evolves over time. A book can be very interesting, but the subject of the book is usually something related to people and/or the real world, Universal systems. The book evolves over time; basically it is slowly disintegrating. The book itself is not a universal system and its evolution is uninteresting; yet it describes systems that evolve. So, all books are uninteresting systems, but the subjects of the books, or even the history of a book, can definitely constitute, along with the reader, interesting systems. This means that the process of us (universal systems) reading a book constitute an evolving system that is interesting.

So when we attempt to create a RUCA, if it can’t do anything interesting, we have not succeeded. Our lack of success can have 2 root causes: first, it might not be Universal, second, it might be universal, but we haven’t discovered how to program it so as to demonstrate its Universality.

Once we see interesting behavior, the easiest path towards proving Universality is the one we discovered at MIT, showing that we can model wires and a logic gate (such as the NAND gate. Once that is shown, the rest is easy. For example, say we have a 2 dimensional CA which we would like to show is universal. Say we have found a wire and a 2 input NAND gate. But assume we can’t seem to find a way to create a crossing where, for example, a North-South wire crosses an East West wire. Do we need a crossing?

The Peculiar Nature of the RUCA

The combination of discreteness, reversibility and universality cause a system to behave in ways different than anything that we are normally familiar with. To appreciate this one needs to spend a fair amount of time working with and watching the behavior of such models.

Informational Connections

In a Universal Computer, that is performing some task, various groupings of information in the memory of the computer have meanings. Such groupings of information can be mapped onto the integers, usually in a way that keeps the meanings obvious. We believe that we can refer to any representations of meanings in the memory of a computer by the word “integer” without any loss of generality. For example, consider a block of bits that an algorithm has compressed that represents a color picture taken by a digital camera. That entire block of bits can be thought of as an integer. It takes a computational process to decode the block to give a set of much smaller integers that represents each pixel.

Finally, another algorithm can break the encoded pixel down into three integers that correspond to the intensities of the primary colors for that pixel.

For a computation to proceed, information must often be connected with other information. What this means is that the computational process computes functions of one or more arguments. When a function of one or more arguments is computed, we say that an informational connection has been made between all the members of the following set {the arguments and the value(s) of the function}. This is similar to a Feynman diagram where a number of particles interact.

All such issues are made clearer by considering a reversible computation as a closed system. This can be done with no loss of generality since a reversible computer can perform any computation that an ordinary computer can do, with approximately the same efficiency. The use of a closed system in thinking about computation is essentially identical to the use of a closed system in making mathematical models of physics. Further, in a reversible computer, the relationship between arguments and values of a function is much more like a Feynman diagram. Rather than focusing on inputs and outputs, one can focus on constraints and relationships amongst all the inputs and outputs of the process.

The Facts of Physics

We will now try to restate the facts of physics with regard to the concepts of space and time in the language of informational processes. This requires one fundamental assumption: space, time and everything else are discrete. We will not address the concept of unit of length except to say it is most likely between a fermi (10^{-15} meters) and Planck's length (10^{-35}meters).

We assume as our most basic principal the concept of informational process. This is a broad concept that describes an extremely broad range of phenomena. We will start with time and space, proceed to computers, and from then move on to physics. The informational process has properties, and we who look at it have ways of thinking about those properties. We will try to keep separate the properties of the informational system from those of us thinking about it.

For an informational process, we assume that time occurs in discrete, ordered steps. We may think of these steps as being numbered t_1, t_2, t_3...t_i... That numbering is not part of the informational process. We assume that during a time step nothing happens, but that change occurs from one time step to the next.

What we will be describing is basically a kind of finite state automata as defined in Minsky's book. However, we do not wish to be so general, because we are only interested in physics. We define microstate by means of a 3+1 space-time coordinate system. The space-time coordinates are something we use to think about the informational system but not a part of it. However connectivity and locality are properties belonging to the informational system. The microstate at x, y, z, t is something equivalent to a small integer. The range (number of different possible values) of that small integer will very likely be 2, 3 or 4. Strangely, we already know that the value of that integer could be 2, 3, 4 or any other integer greater than one. The choice is not a matter of physics but rather a matter of esthetics! The reason is explained in Physics and Computation (a consequence of Universality).

We assume uniformity. This means that the rules (Laws) that govern the behavior of a bounded region of space-time, are the same as for any similar region, regardless of the particular space-time coordinates. There is only one exception to the uniformity rule, and that is at the most microscopic levels of space and time there may be parity rules. These rules are equivalent to creating a space-time checkerboard and/or having a multi-phase clock that that has different rules for each phase of the clock (most likely a 2, 3 or 6 phase clock). Thus the rules (Laws) are the same for any to bounded regions of space-time that are in the same space-time phase.

All of this is prelude to understanding why Mach was right to worry and wrong to assume that the so-called *fixed stars* are the basis for an inertial frame. Since we reject direct action at a distance, what we want to show is that…..

Finally, everything is completely determined by the design of the space, the rules and the state.

Finally we attribute

A computer is an object of physics that, from the informational viewpoint, is in a particular state at a particular time.

Any discrete physics model is equivalent to a CA

There is an atom of momentum and an atom of energy, an atom of electrical charge and an atom of color charge; all very simple.

An atom of energy is a pair of cells in essentially the same place that are temporal neighbors, but are in different states. Energy is related to the temporal frequency of a wave. The smallest part of the wave has to be 2 cells in essentially the same place that are temporal neighbors in different states. Energy is related to frequency.

An atom of momentum is a pair of cells at the same time coordinate but nearest spatial neighbors that are in different states. The direction of the momentum is a function of the triple space-time-state parity

The momentum of a particle is the vector sum of all of the momentum atoms associated with the particle.

The mass-energy of a particle is the sum of all the energy atoms associated with the particle.

An energy-momentum field has the property that it can change the number of energy and momentum atoms associated with a particle.

An atom of charge is an atom of energy that is in one of 2 space-time-state parities.

Every energy atom has charge, but

An atom of color charge is an atom of energy that is in one of 3 space-time-parities. This means that is in a phase that can be identified with one of the 6 directions (3 signed coordinate axes).

What mechanism could result in the equality of gravity and inertia?

The oscillating cells that determine the mass of an object radiate out information into space with perfect long-term superposition.

Thus an isolated mass creates an ever-expanding wave structure that expands out indefinitely.

While the average strength of the wave structure decreases as the inverse square of the distance, this is because fewer and fewer cells per unit area are involved; not because any atom of energy is getting weaker. This is because of the quantization of energy.

Every mass interacts with the energy structure that it encounters. The energy wave structure is the representation of the energy and momentum information. This is what must be changed if the object is to accelerate. Of course, each mass interacts most strongly with its own wave structure.

Coherent in phase interaction is charge interaction.

Incoherent interaction has no long-range net effect.

The source of the gravitational potential is the net energy loss caused by superposition!

Since energy comes in atoms and since the rules conserves energy, there must be superposition.

Since space and time are quantized, 2 independent sources of radiated energy waves that impinge on the very same cell at the exact same time, where each wave would have changed the state of that cell, have the effect of, for that instant in time, not changing the state of that cell. However, because the DM rule allows superposition, the effect is that each wave continues in the same manner as it would have if the other wave were not there.

The result of the DM superposition is that the total amount of energy integrated over the space that is occupied by 2 nearby masses is less than the sum of the energies that that would have been there if each was an isolated mass in space. This difference is proportional to the product of the masses and inversely proportional to the distance between them.

The reason for the balance between inertia and gravitational force is that the inertia is due to the amount of interaction (force) required to change the momentum informational wave. (proportional to the amount of mass-energy). The information that represents the momentum must be changed. The mass is the energy of the same wave. Mass is the time change, momentum is the space change. The wave propagated into space is again proportional to the same wave.

An atom of gravitational potential is a consequence of superposition. Matter is energy and energy is a bit that changes in time (with a wave phenomena, ….)

The information that represents the linear velocity must be local.

The velocity information must interact with the substrate in order to have the particle annihilated where it was and recreated nearby with the same information.

That information must have a means of its representation; convertible into bits.

Acceleration must be produced by a process that changes the local information that represents the velocity.

Angular orientation can be represented by the actual orientation of a particles structure within the space-time array.

N.B. Look for all the references to "velocity" and see if "momentum" is more appropriate.

Programming a Computer

In programming a computer, it is necessary to construct an algorithm. We expect to be able to understand every microscopic aspect of the algorithm, but if it is complex, then we would most likely be unable to understand the long-term outcome of running the algorithm. In fact, this is at the core of much of scientific computing; we run an algorithm to watch the evolution of a system where there is no other way to accomplish the same result. It is easy to show that, in general, there are no shortcuts to getting the answer that will be the result of a *non-trivial algorithm*.

What we are going to look at in great detail is the problem of writing a program to implement Newton's First Law. As originally stated by Newton (in the Principia, 1687 edition, original Latin): "Lex I Corpus omne perseverare in statu suo quiescendi vel movendi uniformiter in directum, nisi quatenus a viribus impressis cogitur statum illum mutare." And as translated from the1725 3rd edition: "Law I Every body continues in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it."

Since we are going to model physics with a computer, we do not wish to cheat and make use of information not available to physics. What we want is to write a program that can model the time evolution of one or a small number of point masses, all obeying Newton's First Law. The computer could then put up a display that shows the points moving or standing still. This seems to be a simple task, and many programs do model the behavior of point masses moving while obeying Newton's first law. However, such programs make use of a coordinate system. Sometimes the reference to the coordinate system is indirect or obscure, but it is always there. The spatial coordinates might be represented by a straightforward x, y and z in IEEE standard floating point format for each point. They might be represented by the position, in a memory, of the number that represents a point mass. However one does it, one can always write another program to recover the coordinates from any program that is modeling the time evolution of such a system.

How do we know this? It doesn't follow from some basic law; its truth is tautological in nature. The way a computer models an information process is to have an algorithm that starts out in its initial state, and then proceeds from one state to the next. To model the time evolution of a system as a succession of *snapshots* at successive points in time, we write a program that takes the state at time equal to t_0 and computes the state at time t_1. This process is continued to compute the time evolution of the state. During this computation, the information that represents the state is processed to compute the new information. There are many variations of exactly how this happens, but the general process is still the same.

For example, for each point particle, there might be a list or table of data such as:

Particle i	Mass	$x_{i, t}$	$y_{i, t}$	$z_{i, t}$	dx_i/dt, Δx_i	dy_i/dt Δy_i	dz_i/dt Δz_i
P_1	100	0	0	0	0	1	0
P_2	100	-10	0	0	1	0	0
P_3	100	10	0	0	-1	0	0

The above table has the data for 3 particles. They are at three equidistant points along a straight line (the x axis). Two of the points would collide (have the same coordinates after 10 time steps, assuming that $\Delta t=1$).

The program could be as simple as:

Set n to 9 [We will do 19 time steps to see if a collision is imminent]

Set Δt to 1 [We step 1 unit of time each iteration]

Set t to 0 [The time is initialized to 0]

Set i to 1 [We start with the 1st particle]

For $P_{i, t+1}$, Set $x_{i, t+1}= x_{i, t}+ \Delta x_i$, $y_{i, t+1}= y_{i, t}+ \Delta y_i$, $z_{i, t+1}= z_{i, t}+ \Delta z$

Set i to i+1 [We get ready to do the next particle]

If 3≥i Go To step 5 [There are 3 particles in the table]

Set t to t+Δt [After the last particle is done we reset to the 1st particle]

If n>t Go To step 4 [We go back for the next time step]

All done [We get here when all 9 steps are done]

This program creates the 4-dimensional manifold with all the trajectories present in their entirety. When it is done, the memory of the computer contains the 9-step trajectory for each point. Of course, its not necessary to keep any data beyond one time step.

We are going to illustrate another program that dispenses with the need for keeping the velocities in an explicit fashion.

We have 2 position data points (a 2nd order system) instead of position & velocity:

Particle i	Mass	$x_{i, 0}$	$y_{i, 0}$	$z_{i, 0}$	$x_{i, -1}$	$y_{i, -1}$	$z_{i, -1}$
P_1	100	0	0	0	0	-1	0
P_2	100	-10	0	0	-11	0	0
P_3	100	10	0	0	11	0	0

This program is similar but different:

Set n to 9 [We will do 9 time steps]

[No need for delta t]

Set t to 0 [The time is initialized to 0]

Set i to 1 [We start with the 1st particle]

Set $x_{i, t+1,}$, $y_{i, t+1}$ and $z_{i, t+1}$ for $P_{i, t+1}$ to $2x_{i, t}$-$x_{i, t-1}$, $2y_{i, t}$- $y_{i, t-1}$ and $2z_{i, t}$- $z_{i, t-1}$

Set i to i+1 [We get ready to do the next particle]

If 3≥i Go To step 5 [There are 3 particles in the table]

Set t to t+Δt [After the last particle is done we reset to the 1st particle]

If n>t Go To step 4 [We go back for the next time step]

All done [We get here when all 19 steps are done]

What is true about both programs, and is also true about any program that computes the same time evolution of the same system, are the following:

There are some kind of data structures whose meanings represents the state of the particles, their positions and velocities.

A computational process transforms the meanings of the data structures that represents the state for one or more points in time (the present and the past) into the information that represents the state at the next future point in time.

The computer information whose meaning represents the position and velocity information of the model must be of such a nature as to be able to be transformed into a set of data based on a single coordinate system whether or not the program actually does so.

For example: the coordinates of each particle could be based on a coordinate system centered on the previous particle. E. g. the coordinates and velocity of P_3 could be based on the assumption that P_2 was always at the origin of the coordinate system that represented the position and velocity of P_3. The first particle's coordinates, P_1 would then be based on the assumption that P_3 was at the origin. No matter; it's easy to transform such a system to either of our examples. From an informational point of view, all of the approaches mentioned are informationally equivalent.

What apparently cannot be done is to eliminate or hide the idea of a fixed coordinate system or its equivalent in any informational process that implements Newton's First Law.

Needs be a Reference Frame

Here is the outline of what could be made into a formal, tautological proof of: The impossibility of computing a trajectory of a free particle without the equivalent of a discrete coordinate system constituting a fixed reference frame. This proof relies on the properties of a RUCA or other exactly reversible models of computation, however it seems likely that much more general proofs are possible.

We define a reversible program, P_1,, as a multivalued function of integer arguments A_i, yielding integer results R_j. $P_1(A_i)= R_j$

Two programs, P_1 and P_2, are equivalent if $\forall(A_i)$, $P_1(A_i)= P_2(A_i)$

We will now define a concept called "derivable".

Given data, D_u , that has some meaning and given other data, D_v, and a program P_{uv} we can say that the meaning of D_u is derivable from the meaning of D_v if P_{uv} exists such that $P_{uv}(D_v)= D_u$.

The object is to use a digital computational process to compute the information that exactly represents the trajectory of a free object as a sequence of states. The definition of such a trajectory must be equivalent to a sequence of ordered n-tuples (x_i, y_i, z_i, t_i,). In other words, whatever digital information is produced to represent the process of the motion of the trajectory, it must be true that there is another process that converts that information into a sequence of ordered n-tuples. Each member of an n-tuple must be equivalent to an integer; chosen from a finite set and having ordering properties. For each such collection of possible integers, there is a coordinate system that maps them onto a space while preserving the ordering properties. This would mean that each distinct point in the space corresponds to a unique n-tuple. Finally, a pair of closest neighboring points in the discrete space corresponds to a pair of n-tuples where the absolute value of a distance function of the 2 n-tuples is a minimum over all pairs of n-tuples. That, plus a few other obvious provisos means that whatever data is produced by a digital informational system modeling the motion of a free particle allows one to plot that data on a discrete coordinate system. The same is true of digital models of any type of particle motion.

There is no digital informational process that can model Newton's First Law (and all other laws of motion) without there being the necessity that one can derive from the digital informational process the equivalent of a preferred, discrete coordinate system.

By assuming the truth of the above statement we will be able to gain new insights by looking at one more informational models of our 3-particle system. This time instead of a computer model, we will make a physical model involving 3 small, identical spheres in a zero G environment aboard the Space Shuttle. We will use some kind of apparatus to hold the spheres in their initial positions and at a certain time, to simultaneously launch them into their respective motions. Two video cameras connected to a computer could capture a sequence of x, y, z, positions of the 3 spheres. The table of data that could be generated by that program could match exactly that of the previous 2 programs; 19 sets of coordinates for each of the three spheres. From an informational point of view there is no real difference between this last method of computing and the other 2 methods. The point still remains that: *There is no digital informational process that can model Newton's First Law (and all other laws of motion) without there being the necessity that one can derive from the digital informational process the equivalent of a preferred, discrete coordinate system.* What we are trying to say is that there is a fourth law of motion: *Newton's First Law implies the equivalent of a coordinate system, accessible to the process that creates motion.* And the Fourth Law must be true whether or not we happen to be conducting an experiment.

The Fourth Law is a consequence of something outside of what we currently think of as *physics*. Of course, physics must eventually grow to incorporate informational issues because they are part of the world we live in. However today, in the year 1998, the kinds of informational knowledge that would let us conclude the validity of the Fourth Law is not yet a part of Physics.

What we know and don't know

In Physics we discover things and their mathematical relationships.

It is like a kind of dictionary and grammar written in the language it describes.

Physics has no answers when we get to the most very basic questions:

Why are there particles, energy, momentum, charge, relativity… ?

What is the explanation of motion?

How do particles know what to do?

Relativity & QM

Newtonian Mechanics and the Theory of Relativity have one thing in common. Both were largely developed by one person, Newton for Classical Mechanics and Einstein for Relativity. Newton had, in addition, the task of extending mathematics to the differential and integral calculus. Of course, others did groundwork or contemporary accomplishments. Galileo and Leibniz in Newton's time and Poincare, Lorentz and others in Einstein's time. The story of Quantum Mechanics is very different! It starts with Planck and Einstein, whose discoveries opened the door to the concept of light being quantized. What has followed and what continues today is creation of the most amazing set of intellectual structures in the history of science. This was not done largely by one giant intellect as it was for Classical Mechanics and for Relativity. Rather, a veritable army of intellectual giants has labored for a century; and Quantum Mechanics is still work in progress.

The problem is not that there has been no Einstein or Newton like person to simply do the whole task without any help. On the contrary, the number of brilliant, creative and dedicated scientists working in the frontiers of microscopic physics has been astounding.

The problem is not who but what. Quantum Mechanics is not only difficult and complex it is unintuitive and alien. As Feynman once said, “No one understands Quantum Mechanics.”

Conservation Laws

One of the most useful discoveries in physics are the conservation laws. We can deduce what might possibly happen in many kinds of physics experiments by simply taking into account what is allowed by the various conservation laws. Conservation laws have another little appreciated characteristic: applying true conservation laws is useful, but imagining a conservation law that is false, does not always lead to wrong conclusions. A good example: Sidi Carnot believed in the Caloric Theory (which had a law of Conservation of Heat). But Carnot’s proof of the impossibility of producing a heat engine more efficient than the Carnot engine was correct, despite the falseness of the caloric theory. In DM we assume, with no real evidence, that the bits in the computation are conserved. We further assume that the information that the bits represent is also conserved. These assumptions are reasonable since the RUCA is universal. The only question is “Do these two conservation assumptions result in a simpler model or a more complex model?” All our experience suggests that it results in a simpler model, but always remember: If any CA (CA, UCA or RUCA) can do physics exactly, then all UCAs and RUCAs can also do physics exactly!

Mach’s Principal, Newton’s Question

Speed of Photons

If we subscribe to the Feynman picture of QED, where electrons interact with photons, then it is possible to paint an interesting picture of light and the photons. Perhaps the most fundamental of all natural constants is the speed of light, c. However, the speed of light is not really a constant unless it is traveling in a vacuum. When traveling through a transparent medium such as water or glass, the speed of light is less than c. On the other hand, the speed of a photon is always c! Perhaps the constant should be called the “Speed of Photons”. We are going to discuss the life and death of a photon as seen from the perspective of the photon.

A photon is evidently born in the presence of an electron and another photon. We say that when an electron is accelerated, radiation occurs; the electron emits a photon. But how is an electron accelerated? In QED an electron is accelerated by the absorption of a photon. The conservation laws for charge, angular momentum, linear momentum and energy define the details. We will look closely at a photon, from 2 points of view: the first will be what we call subjective time.

This is the time as measured by the photon, or by someone with a clock that hitches a ride along with the photon. Of course, this would be impossible for anything with non-zero rest mass, but we can imagine it anyway. The second will be the objective time of some ordinary observer.

So, a photon is absorbed by an electron and the electron emits a photon. The birth process of the photon lasts for about ½ of its subjective lifetime. That process is quite interesting, as the question of what are to be the inherited characteristics of the photon get settled during the process. There may be many choices or there may be no choice whatsoever. If there are many photons present, all in the same state as one might find in a laser, then the photon has a high probability of becoming essentially a clone, being born with the same state of energy-momentum and direction. It is also approximately true for a photon's interactions with mirrors and lenses. In such cases, a photon is absorbed by an electron and then a near clone is emitted by the electron. Many of the properties of the absorbed photon are retained in the reemitted photon, but some (the direction of propagation, or the frequency in the case of a moving mirror) may be altered.

When the electron is radiating heat from a hot atom, the photon takes on a personality of its own. What happens still obeys all the conservation laws, but nevertheless each photon is more or less on its own as to what it is, within a range of energies but taking any possible direction. So it seems, yet the energy and momentum of the photon consists of those energy and momentum atoms, which belonged to some other near-by entities. What they give up to the photon, the photon takes with it. This poses as interesting problem insofar as the momentum atoms. As will be explained later, momentum atoms come in 6 kinds; ±X, ±Y, ±Z. If there is a +X momentum atom, there cannot be a –X momentum atom; the same for Y and Z. One of our DM models for rest mass involves what we call frustrated momentum. This involves diametrically opposed momentum atoms that add up to zero. The concept is that perhaps the presence of 2 or more atoms whose momentum cancels out, results in rest mass. A photon has 0 rest mass.

Once the birth process is over, the next ½ of the photon's subjective lifetime begins without delay. The photon starts the process of dying. This takes place as the photon is absorbed by an electron. What is unusual about photons is that while their entire subjective life consists of the birth process followed immediately by the death process, the birth and death can be separated by enormous distances, even on an intergalactic scale. You see, after the birth process is over, the photon is traveling at c, with the consequence that its clock (perception of time) is stopped. Thus nothing about the photon, from its perspective, can be changing. Thus we see that, in reality, a photon is an unstable particle. Any unstable particle gets its objective life extended as it approaches a velocity near c. Thus aside from birth and death, the lifetime of a photon is 0 seconds.

We want to understand a photon from its own perspective. It can be born in the company of a charged particle and a dying photon. When it dies, it can do so in the company of a charged particle and a newly born photon. We assume that all photons always travel at what we call "the speed of light", but at what perhaps should be called "the speed of photons" (in a refractive medium light travels slower than the speed of photons). From the photon's point of view, as a process, its entire life has exactly 2 stages, the first ½ of its life involves its birth and the 2nd ½ of its life involve its death. Between birth and death a photon might travel for billions of light years of our time, but no time passes from the perspective of the photon, since at the speed of light, its local clock is effectively stopped. Death is most often followed by reincarnation, often as a near clone as in transmission through transparent media. The reason that the speed of light is slower than c in a refractive medium, is that though the photons travel at the standard speed of light, c, time is lost as they are absorbed and then reemitted. Sometimes that reemission is as a symmetric but different clone (reflection from a mirror) and sometimes as something quite different (scattering). Photons (because they are spin 1 bosons) are gregarious in that at birth they are likely to join in with other photons into the same state. The DM model suggests that the energy of a photon is defined by the number of energy atoms in its nucleus. The momentum of the photon is defined by the vector sum of momentum atoms in its nucleus. The direction that it travels in is defined by the extended informational wave structure that is spread out in space. The informational wave structure of a photon can interact with the wave structures of many electrons simultaneously (as is the case with mirrors and lenses) but the nucleus of one photon can only interact with the nucleus of one electron.

The Electron

We also want to look at an electron from its own perspective. Normally, electrons are fraternal twins born in the company of photons. We usually explain that electrons and positrons are created in pairs and annihilated in pairs because of the conservation of lepton number. This is not an explanation but rather a principle that matches our observations. After it is born, an electron is essentially an inertial object until and unless it has an interaction with (normally) a photon. The photon dies and is reincarnated, and depending on how the photon is reincarnated; the momentum of the electron is changed. From the DM perspective this is very simple: the atoms of energy and momentum contained in the nuclei of the incoming electron and photon are combined and then separated into the nuclei of the outgoing photon and electron. Exactly how this is done depends a lot on the overall environment.

The Uncertainty Principle

The Uncertainty Principle puts limits on what we can measure. However what it says we cannot measure is normally obscured by a simplistic statement of the principal. "*You cannot make a simultaneous measurement of a particles position and momentum (or time and energy) more precisely than values that limit the product of the measures to be greater than* ∇ *(Planck's Constant Reduced)*." That statement is incorrect because it fails to specify that it is knowing the present position and determining at that time what the future momentum will be is the only thing that is ruled out. It is not ruled out by any relationship of wavelength and energy, but rather because of the QM correlations that determine microscopic behavior. (Note, Make a reference to recent Which Way experiment with Atoms passing through one of 2 slits formed by a standing wave from a laser). All the thought experiments of observing which slot the particle passes through with a photon , where the photon must have enough energy to enforce the uncertainty principle by altering the path of the particle turn out to be incorrect. It is trivial to arrange for a Gedanken experiment that will measure, with arbitrary precision, the current time and prior energy or the current position and the prior momentum of a particle.

Imagine an evacuated tube, perhaps one meter long and 10cm in diameter. At each end is a specialized silicon chip, about 2cm x 2cm. The chips are microscopic impact detectors. They are able to provide 2 kinds of information when a particle bounces off the surface of the chip. The information is the time and location of the impact. The interior of the tube is empty; no particles, no gross electrostatic or magnetic fields. We introduce into this tube a single particle (such as a $Helium_3$ atom, traveling at 100 meters per second) aimed at the distant chip in such a way as to have a high probability of reflecting off of the distant chip and impacting the near chip. When the particle collides with the distant detector, we measure the time and position of the impact. So far we don't know very much. However, when the particle collides directly with the near chip, we again measure the position and time. It should be possible to measure the position to an uncertainty of a few microns, and the time to an uncertainty of about a nanosecond. We now know the past momentum and position with high precision. In this case, the uncertainty of the (momentum uncertainty) x (position uncertainty) product is about $2\ 10^{-37}$ Joule Seconds. That measured uncertainty is about 500 times less than Planck's Constant, ∇ (about 10^{-34} Joule Seconds). What we don't know at that time is the future momentum. It could be determined by again detecting the particle on another detector. It is quite likely that experiments may be thought up that reduce the uncertainty in simultaneous measurements of present position and previous momentum to as small a value as desired. Of course, we still don't know how to arbitrarily determine both the present position and future momentum of a particle with uncertainty less than ∇ .

A better statement of the Uncertainty Principal is "You cannot simultaneously measure the present position and determine the future momentum with arbitrary accuracy."

Where is the information? Why is there a relationship between position and momentum? Why is there a relationship between energy and time? Here we must resort to Occam's Razor. There is no good reason to suppose that it is anywhere remote from the particle. The assumption of the particle being one place and the information that determines its behavior being somewhere else and far away is tremendously and unnecessarily complicating. If there is an informational structure that represents both what kind of particle it is, and its spin and momentum information, then its spatial information can simply be represented by where the momentum and other state information is on some coordinate system. If the position information happens to be the location on the grid of the momentum information, then position and momentum would have to be complementary.

Similarly, energy information and time coordinates information would have similar complementarity. This will be made clearer when we discuss dimensional units.

Interference, a property of all particles

The detailed explanation within DM for the fact that momentum and energy are conserved in particle interactions has to do with the concept of atoms of momentum and atoms of energy, which are conserved. Obviously this means that the conservation based on such atoms must be related to a preferred reference framework; relying on other mechanisms to maintain Lorentz Invariance in other inertial frames. This may strike one as overly complicated but we believe that the whole picture is thereby made strikingly simpler.

The informational wave structure carries the precise directional information. This is best illustrated by having a particle pass through a tiny hole. If the nucleus gets through but most of the informational wave structure does not, directional information is lost. This is a mechanistic explanation of part of the uncertainty principle. If we locate the present position of a particle with some amount of precision, the future momentum becomes less certain. This process of locating the particle can be done in many ways, but not normally without affecting the informational wave. Diffraction and other wave like phenomena are related to the informational wave structure.

As a photon and an electron approach each other, their informational wave structures start to interact. The kind of positional (or momentum) shifts that occur in interference, can occur to adjust the positions for interaction or to adjust then to miss the interaction. The exact nature of the interaction has to do with how information interacts. If the electron is going to be accelerated, then there has to be a mixing of the momentum-energy information of both particles. This mixing is followed by separation, so that the 2 particles leave the site of the interaction, having changed energy and momentum. The conservation of energy and momentum is enforced by the fact that the number of energy atoms is fixed and therefore, however they are divided up between the 2 particles, the totals are fixed. The same is true for the momentum atoms.

Let us consider the DM view of a classic interferometer experiment. Photons are directed at a 1/2 silvered mirror. What follows is the DM view. DM states that the nucleus must either be transmitted or reflected, but that the informational wave does both. The informational wave carries no energy or momentum and it can be split with little loss of information as to direction, location and phase. Upon being reunited at the surface of a second mirror, the two informational waves will interfere either constructively or destructively, and the photon will be transmitted or reflected as is appropriate. This process might enable us to be able to build a device that generates coherent informational waves that can be transmitted and detected without transmitting any energy. Such an apparatus will be described below.

We start with a laser with a very long coherence length. If one can build a clocked source of single photons (as has been done for electrons) it makes the device much simpler. We attenuate the output until we have about one photon per meter. We pass the photons through a 1/2 silvered mirror. On the reflected side we have a PM tube. On the other side we have a Kerr Cell shutter. When we detect a photon on the reflected side, we know that an informational wave (without a nucleus) is on the other side. When that happens, we open a shutter to let the informational wave through; otherwise the shutter stays shut. This gives us a stream of coherent informational waves that should be detectable with a source of very similar photons in another interferometer. Of course, in the apparatus as described, an occasional nucleus could slip through on the informational wave side.

Analog vs. Digital

Let us consider a clock as an example of analog vs. digital. Consider a regular analog clock (with hands that are in continuous smooth motion) in an analog universe (time flowing continuously). Let us assume that when we detect that it is fast, it is slowed down and visa versa. We will try to servo the clock to the time kept by the master clock.then it normally never has the exactly correct (analog UTC as kept by a Master Clock) time. Let us assume that . However the cost of smooth continuous motion is the implication that infinite informational resources of some kind are needed for the clock to be able to have absolute continuity of position and motion. However, if the clock is stopped, then we know that it will show exactly the correct time twice a day.

If we have a digital clock in an analog universe where the time is displayed in digital form as hours, minutes and seconds, then if it is reasonably accurate and if it has been set to be 1/2 second fast, then it will show the exactly correct time once each second! Our digital clock requires only finite resources but in an analog universe it's hard to avoid infinite resources even if you don't need or want them.

In a digital universe, our standard of time would be the same as the basic underlying digital process. It is then possible to build digital clocks that, during each unit of clock time, show the exactly correct time for exactly one unit of digital universe time. There is no need for anything more than a moderate, finite amount of resources for the clock.

We know of no evidence that *Finite Nature* is incapable of modeling the world. We believe that the concept of continuous space and time (and of other continuous quantities of physics) implies a need for infinite resources to exactly model the tiniest regions of space-time. We invoke Occam's Razor to choose a model requiring only finite complexity as opposed to infinite complexity.

Is Physics Computation Universal?

The question of the computation universality of physics transcends the question as to whether or not Finite Nature is a correct assumption or whether or not DM is a good model of physics. "The basic processes of physics are Computation Universal." is either a true statement or it is false. There is no middle ground. It doesn't matter what other laws of physics turn out to be true or false. We are going to describe a property of physics, *computation universality*, that could be either true or false, we will then explain our hypothesis and discuss the results of experiments.

The definition of "computational universal process" follows:

We start with a *system* that has the property that it evolves through different states over time according to certain rules or laws (physics is such a system). In physics, we have matter-energy (particles) that can represent states in a number of ways. The fundamental process of that system can be proven *computation universal* if it can be demonstrated that the rules and laws (of physics) that govern the existence, motion and interactions of the things that have state, allow for the construction and operation of a universal computer within the *system*. What has to be understood is that any system, no matter how complex or interesting, can only be proven to be *computation universal* by showing that within the *system*, a *computation universal process* can be constructed and operated.

Let us imagine that long ago, an alien from another universe (different physics) visited our universe. He might wonder whether physics in the universe he was visiting was *computation universal*. To answer the question, he would have to convince himself as to whether or not it was possible to construct a *computational universal process* within our physics.

Thus, what is needed is experimental proof that we can construct, within the laws of physics, a computation universal process. The experiment has been done and repeated billions of times! It may be the only experiment whose results have been independently verified in every city on Earth. The experimental results are always the same. Since essentially every computer that is manufactured these days is computation universal, this can be characterized as a large experiment, even by the standards of high energy physics.

Alan Turing[20] invented the concept of a Universal Computer before the age of electronic computers. In his paper, he demonstrated that a simple minded clerk, with nothing but a pencil, an eraser and a long one-dimensional piece of paper, guided by some very simple rules, was a computation universal system.

There are Quantum Mechanical models of computation, some of which use gates such as the conservative logic gate or the Toffoli gate, where it has been shown

[20] Reference Turing's paper

that we can construct, within the model, a Universal Computer.

There is a classical (Newtonian) model of computation (the Billiard Ball Model[21] or BBM) wherein it is easy to demonstrate that we can construct a Universal Computer within the BBM. A BBM computer is

In any case, a theoretical model such as the BBM, which assume everything operates perfectly without error, cannot replace true experimental verification. The real experimental proof requires that we actually build a Universal Computer and demonstrate that it meets the criteria.

Of course, essentially every computer built in the last 50 years has been Computation Universal!

Gedanken Experiments

There are physical experiments and thought experiments. Some thought experiments are plain nonsense; others are dramatic and obviously compelling. Consider Galileo's wonderful thought experiments found in *The Dialogues Concerning the Two New Sciences*. Discussions between the interlocutors: Salviati, Sagredo and Simplicio serve to construct a common sense understanding of physics. Questions are raised and answered. Understanding is enhanced. The discussion covers extensions, generalizations and variations of situations related to actual physical experiments. This process is important to the development of a science. A carefully crafted thought experiment can contribute as much to our understanding as the most carefully crafted physical experiment. It can also lead us astray. It is hard to argue with the following variation of a classic thought experiment as to why, in the absence air resistance, an object with twice the mass of another should not fall twice as fast as the lighter object.

Consider three identical objects. Obviously, each falls at the same speed as the others. If they are simultaneously dropped from three nearby positions at the same height, they will all hit the ground at the same time. So far, this seems clear. Let us repeat the experiment but this time we will connect two of the objects with a very fine thread. Now, when we drop all three objects, we expect the results to be the same. We can keep increasing the strength of the thread and the closeness of the two objects as we keep repeating the experiment. It seems absurd to imagine that at some point the 2 connected objects suddenly decide that they are now one object (bound into one object by lots of thread) and therefore must suddenly have to fall twice as fast as the third object.

Creating good thought experiments can be very difficult. There are subtle hazards along the way. The trouble with the thought experiments is that it hard to realize what assumptions go into them. It is easy to imagine a world where arrangements of gravitational masses and accelerations give results at odds with what we observe here on Earth. A simple example is when the planetary mass is only a modest multiple of the mass of a dropped object. Then a heavy dropped object would clearly reach the ground in less time than a light weight object, unless they

[21] The Billiard Ball Model is described in Conservative Logic, ***** reference

were both dropped at the same time from approximately the same place!

What all this preamble is getting at is that we propose to lead you through a set of thought experiments, our purpose being to convince you to reject the framework created by an earlier set of thought experiments. We have no quarrel with any generally accepted experimental data. We have no quarrel with any of the accepted mathematical models insofar as they represent ways to calculate accurately. Our quarrel is prompted by new information and knowledge, not available in the past, which we feel must render many currently accepted concepts simply incorrect. The old concepts were arrived at through thought experiments and generalized conclusions that go beyond the mathematics or the experimental data, but which have profited us so far by creating an understandable framework. We now need to reconsider that framework because, as you shall see, we have new ways to poke holes in many of the conclusion based on that framework.

A Bit of Numerology?

There is reason to believe that an electron has a structure that includes a component that represents the rest mass. Starting with the hypothesis that perhaps the rest mass of a fermion is an integral number of rest mass atoms, we found the following. Current data (CODATA 1998) is compatible with an electron having 13 units of rest mass and a muon having 2688 units. We note that some of the geometries we are considering involve a Face Centered Cubic structure where the cells are like packed spheres. A *sphere* surrounded by another 12 *spheres* (13 in all) is a reasonably symmetric structure. Each *sphere* might be a rest mass atom that contains opposing momentum atoms. One can thinks of a pair of opposing momentum atoms as an atom of rest mass. Thus an electron might have 13 atoms of rest mass. For a Muon, we imagine a sphere of 2688 rest mass atoms. This might be in the form of a symmetric sphere of 2731 with a cavity of 43 (another symmetric sphere), resulting in a reasonably symmetric structure. While we have no reason to understand why, a Proton ends up, in this model, with 23870 atoms of rest mass; again to the accuracy of current experimental data. Of course, a proton is a complex structure without an apparent path to a simple calculation of its rest mass.

We will examine the case of the emission of a photon of light by an electron accelerated by a field (photon).

First, a few comments. Some of these ideas and descriptions are not physically correct but they are useful in order to generate a complete picture. We choose to be very informal and anthropomorphic in our language in order to lend some kind of reality to a picture that is quite foreign to human experience. For example we can think of charge as sex -- opposites attract and likes repel; usually. As we are able to provide more and more physically correct aspects of the microscopic characteristics of particles we hope to continue to adapt our global picture.

Notes

Finite Nature implies certain consequences:

The fundamental processes of physics must be similar to what are called "Finite State Automata". Automata are the class of discrete systems that evolve according to *Rules.* Further, if Finite Nature is true, the entire Universe must be a Finite State Automata! This is a true but nearly useless observation.

Behavior of microscopic processes of Physics would be isomorphic to Reversible Automata.

In particular, the exact state of any volume of space-time could be exactly represented by a finite number of bits.

Experiments and the Unit of Length

Every so often there is a published report that describes some new physics experiment that bears on discrete length. The point is usually to claim that the experiment shows that if space is a discrete lattice, the unit of length (lattice spacing) must be less than ε. While the claim is undoubtedly true for many models of discrete physics, we shall explain why it is essentially never true for DM models of physics. The reason is very simple. In DM, when two particles interact, the effective coordinates of the interaction site are a consequence of a computational process in the DM. We will give a simple example to clarify the concept.

Consider a Cartesian lattice of 10^9 cells, where each cell can hold one bit, arranged into a 1000x1000x1000 cube (a total of about 125 Megabytes). Assume that we are using that cube to represent 10^9 fermi^3 of space (a fermi is a unit of length equal to 10^{-15} meters). Thus each cell measures 1x1x1 fermi. Further, let us suppose that we represent the presence of a particle by setting a bit in a cell to a one, where zero represents the absence of a particle. This means that the 3 coordinates of a single cell, which contains a 1 or a 0 has a precision of location of one fermi.

As always, we assume an informational process that is able to properly interpret the information.

We are now going to modify the model and instead of using a block of one bit to represent the position we will use a 10x10x10 block of bits (1,000 bits). This means that our model can store fewer particles, but with more information per particle. Of the 1000 bits per particle, we allocate them as follows: 256x3=768 bits for x, y z velocity components, 64x3=192 bits for high precision x, y, z, micro position information and 40 bits for miscellaneous (charge, spin, kind of particle, etc.). Now, the entire 10x10x10 block can still be located with the same precision as the previous 1 bit/particle model (a precision of 10^{-15} meters). This is true because despite the size of the block, it can still move over by just one cell in the array. Then we must account for the high precision micro position information where we have 64 bits each for x, y and z. 2^{-64} is about $5x10^{-20}$. As a result, the overall precision of location of each particle (the precision available to the program that determines how things move and interact) is about $5x10^{-35}$ meters.

On the downside, using a block of bits means that a tiny space can hold fewer particles. However if all of the particles are bosons in the same state, we could merely use some of the miscellaneous bits to indicate the number of such particles. As for fermions, you can't have 2 or more in the same state anyway. What has to be understood is that it is trivial for a simple informational process to treat our 10x10x10 block particle as though it were a simple particle with a precision of location of 5×10^{-35} meters. This precision of location does not mean that the particle has a location with that precision, it merely indicates the number of digits of positional information available to work with interactions and other processes.

The 2 examples given above are merely to make a single point; in DM, the lattice spacing is not necessarily tied to the positional resolution of particle interactions. We could wish that the unit of length will be greater than a fermi; allowing for interesting calculations using commercial computers. However, the unit of length will not be what we wish for, but rather what it is.

Professor John McCarthy of Stanford has made up a large number of wonderful tales that illuminate interesting ideas. He tells one of Galileo being in the Cathedral in Pisa, praying, when he noticed a large hanging chandelier swaying back and forth. (Whoever had lit the candles had set it into motion). Watching it, it occurred to Galileo that perhaps each swing of the chandelier took nearly the same amount of time, independent of the amplitude of the swing. So, Galileo started to time the swings, comparing them with his pulse. It so happened that in that holy place, God was eavesdropping on Galileo's thoughts. And God reflected "So far, no one has noted that as a pendulum swings, each smaller swing takes less time than a larger swing and Galileo is a pious man. Why don't I grant him a boon? Since no one understands physics yet, it shouldn't be too hard to rearrange all the laws of physics in a consistent way so that Galileo's hypothesis becomes true, from now till eternity, without anyone being the wiser." Unfortunately, we are not as pious as was Galileo. As God thought it; and so it was done." Unfortunately, we are not as pious as was Galileo.

The Michelson-Morley Experiment

"…what is proved by impossibility proofs is a lack of imagination."[22]

The attempt to measure the speed of the Earth through the ether failed, and that failure led to the Theory of Relativity. The method used was to send a beam of light down a set of paths (in different directions) and, in essence, to measure how long it took to traverse the paths. What was discovered was that the time for light to travel a given distance was independent of the velocity of the Earth through the cosmos. Neither the Earth's rotation on its axis (where the speed of the laboratory changes by more than 1,000 kilometers per hour during a 12 hour period, nor the Earth's motion around the Sun had any effect on the measurement.

While the theory of Relativity is one of the greatest intellectual achievements of all time, it is not the entire story as to the results of the Michelson-Morely

[22] J. S. Bell

Experiment. With an AT-Clock, it is a simple matter to measure the velocity of the Earth through a defined, standard reference frame. This is not quite the same as finding the velocity of the Earth through a fixed, natural reference frame. On the other hand, it reduces the problem to one of finding the fixed reference frame! What needs to be completely understood is that the Mathematical Theory of Relativity is a fantastic, wonderful, accurate model of the way things work. We can use the mathematical formulae with great confidence. However all the literature written about the Theory of Relativity, including works by Einstein, are not a legitimate part of the Theory of Relativity. If somehow, there is an experimental result that accurately measures the relative velocity of the center of mass of the Universe (in laboratory coordinates), it won't mean that the mathematical Theory of Relativity is wrong, it will just be that a lot of verbiage is no longer acceptable as representing what the theory means.

We now can go to Einstein's explanation of the Relativity of Simultaneity and show why the conclusions he arrives at in gedanken experiments are not the only possible ones!

After examining Einstein's picture of relativity (but not the math) we go to Newton's First Law and explain how it must work. Then we go to Mach's Principal and show that he was right to be bothered but wrong in his solution. Finally we complete arguments on why there must be an absolute reference frame. The Mathematical Theory of Relativity is obviously correct but most of the natural language (German, English, et al) explanations of the consequences of the correct mathematical theory turn out to be dead wrong!

In summary, we will argue that there must be a preferred and accessible absolute reference frame. That the absolute reference frame allows the determination of absolute velocity relative to absolute coordinates, that the rate of absolute time may be determined (and even possibly the absolute time!) and that absolute angular orientation can be determined (relative to fixed but not labeled coordinate axes.)

All this is contrary to the beliefs of almost every educated person. Before we try to explain it all, we have to set the stage.

The Equivalence Principle

It would be nice if we could assume that in the cases where an acceleration field is locally indistinguishable from a gravitational field, then it makes no difference to the AT-Clock. We do not believe that assumption. The reason is that we can imagine hypothetical gravitational objects and journeys that take place in the vicinity of those objects, that will cause the AT-Clock to fail to keep proper time without knowledge enabling the separation of the gravitational and acceleration effects. The solution we propose is to know about all gravitational objects by starting out with a good local library and by having good means of augmenting the library through measurements and calculations as the clock travels through space.

The Properties of New Particles

Let us assume that a new atom is discovered and called “Unicorn”. Perhaps it is an unanticipated heavyweight with atomic number >114. It might be that it doesn't exist in nature, but can be made by physicists. We naturally expect that despite the artificial origins of this new atom, it will be governed by the same laws of physics, as are all naturally occurring atoms. The laws of physics cannot be expected to make distinctions between what occurs naturally and things made by man and his tools. Assume we discover an amazing property of the new atom, angular anisotropy of its spin 1 state. Here are the imagined facts: Simple experiments on Atom Unicorn allow the determination of particular fixed directions (astronomical directions related to the fixed stars). What one observes is that it is possible to build an instrument using beams of such atoms that accurately determine the angular orientation of a fixed set of coordinate axes.

Again, stretch your imagination to assume that the experiment is rock solid and easily duplicated and always gives the same results. We won't like it! However, we can ask various questions: Is this because atom Unicorn was made by man and therefore is an unnatural thing; exempt from our cherished picture of angular isotropy? Should we decide that our picture of nature should remain unchanged and just exclude atom Unicorn from the realm of nature? Is it because Unicorn is more complex than other atoms and therefore it successfully cheats?

And then, what if the rule of no absolute angular anisotropy in space turns out to be wrong. Which equations of physics become invalid? What previous experiments gave false results? The answers are perfectly clear. No equations of physics become invalid. Not even Noether’s Theorem. Previous experiments are not invalidated. It’s just that we hadn't noticed angular anisotropy before. There once was a time before we noticed subatomic particles. That didn't mean that we had proved that they didn't exist.

Today any camper can buy, in a camping goods store, a handheld GPS that can always give the camper her location to within a few meters. It may not know which way is north, but if the camper starts to walk, it immediately tells her which way she is headed.

Let us imagine that we cut open a newly arrived meteorite and inside it we find something, an alien artifact, that closely resembles the camper's handheld GPS. Except this device seems to be an intergalactic GPS. It also contains a digital tape measure; you pull out the tape and a dial on the device indicates how long the pulled out tape is. It not only shows which way the holder is walking (as does a GPS, but it references a different coordinate system than Earth's latitude and longitude). It shows the rotational and orbital motions of the Earth, the path of the solar system, the drift of the galaxy and the time in terms of some large integer that is counting up at a high rate. After noticing how many counts per hour, we conclude that the count was zero some 13 billion years ago. It doesn't just tell time, maybe it tells ***the*** time! What is clear is that the device can measure position and speed relative to some particular, fixed (preferred?) framework. Extensive tests give very bizarre results. The clock indicates a version of time that doesn't slow down at relativistic speeds and the tape measure gives lengths that don't shrink in the direction of relativistic speeds. (The mass, however, does increase at relativistic speeds!) Like atoms of Unicorn, it also can point out which way is intergalactic east, down, south, west, up, north. Does its existence violate any previous experimental data? The answer is clearly "No". No, it is not in violation of any experimental data. No, there is nothing in the mathematical laws derived from the data that indicates that such a device cannot exist. All it does is violate our concept of what we have come to believe is true of physics, based on thought experiments, generalizations, extensions and natural language explanations that expand the domain of the mathematical laws based on experimental evidence. The reason we still hang onto our philosophical beliefs about Relativity is that we haven't discovered an atom with the properties ascribed (tongue-in-cheek) to Unicorn. We haven't found an alien artifact like the intergalactic GPS.

Today, just as we can make a W factory to study the properties of an exotic particle, we can also open a factory to make AT-Clocks (with tape measures). Since all that is required is some kind of natural oscillator, a computer and various sensors, there is no a priori reason why it cannot be designed and manufactured. The way an AT-Clock works is as follows: Basically, it has a computer, an atomic clock and an advanced inertial navigation system. It has extra sensors in order to measure such things as the gravity gradient. It is initialized so that it know its position, velocity, orientation and the time. In addition, it knows about all nearby gravitationally significant masses (such as the sun, planets, moons, etc.) and about their orbits. If you're worried about drift (the sensor outputs have to be integrated and errors could accumulate and grow) there are many ways to compensate. For example, if our AT-Clock is out in space, it could take measures of various stars from time to time to zero out drift. For use in extreme conditions, it can keep track of and remember the gravitational tensor throughout its trajectory and thereby avoid any confusion between gravitational effects and acceleration effects. Each clock would be synchronized to UITC and to the preferred coordinate frame prior to leaving the factory. From that time on, it keeps a complete history of its entire trajectory through space-time. Of course, it can display pictures of several different clocks on its display screen. The simplest would be local time, another might be UTC and another could be UITC (displaying time and all other significant spatial measures). A radioactive power source could power each AT-Clock for 1000 years (measured in local time, not UITC!). Such devices could be dispersed throughout our part of the galaxy. Anyone finding such an AT-Clock would find it similar to the hypothetical atom Unicorn or to the alien intergalactic GPS. The question is: "In what way does an AT-Clock differ from the hypothetical Unicorn atom?" Well, the Unicorn atom only abolished angular isotropy. The AT-Clock abolishes philosophical concepts associated with both Newton's and Einstein's Relativity. It abolishes the impossibility of doing many things that we are told can't be done. Examples include determining the simultaneity of events in different reference frames. Physics experiments become possible that can determine speed with respect to a standardized reference frame. Angular orientation can be determined with respect to a standardized set of coordinate axes. All that is needed is to make use of one of the creatures of physics, not a light beam, not a yardstick, not an ordinary clock, not atoms of element Unicorn, but an AT-Clock!

A Natural Absolute Reference Frame

What is also very strongly suggested by this point of view is that there is no longer a good reason to insist that there is no natural absolute reference frame that might be detected. This may be true despite the Law of Conservation of Momentum. The fact that we can derive the correct law of Conservation of Momentum from the assumption that there is no preferred reference frame in no way implies that there is no preferred reference frame! What is true is that the calculation of the total momentum of a closed (isolated) system will remain constant as the system evolves. While different reference frames will give a different value for the total momentum, whatever reference frame is chosen the value of the total momentum in that reference frame will remain constant as the system evolves.

Similarly, there is no reason to believe in the necessity of angular isotropy, despite the correctness of the law of conservation of angular momentum (as will be discussed later). There is no reason to believe that velocity must be relative to some object or to some arbitrary reference frame.

Another Nail in the Coffin!

We will try to point out why some of what the philosophy of the current theory of relativity demands is an informational impossibility. Of course, we are not talking about the mathematical laws and their proven consequences. We know that at relativistic speeds ordinary clocks slow down, we know that relativistic speeds result in increases in mass and contractions of length. Of course! However all of that does not say we can't define and then measure velocity relative to a distant standard. It does not say that we can never discover absolute velocity. It's just that the methods that work great for measuring relative velocity can be shown incapable of measuring absolute velocity. So what! In an airplane, the old instruments could measure airspeed (the speed through the air) but since the wind blows and the air moves, it was once thought that no instrument wholly contained in the airplane could measure the absolute speed over the ground, independent of the wind. MIT's Charles Draper invented inertial navigation and now we know better. Similarly, all the examples that show why sending light beams thither and yon can't solve the problem of measuring the simultaneity of events in different reference frames are just proofs that us physicists are not as good at engineering problem solving as we are at theory. Finally, the very method of attempting to prove what you can't do by giving examples of several different ways that you can't do it, is plain silly!

The big question is "What do we want to know?" If we want to measure time and space with ordinary clocks, light beams and measuring rods, so be it; we are free to try to do so. It's our choice. We can also choose to establish (or perhaps find) a single fixed reference frame for space, orientation and time and make all our measurements with respect to that frame. Just as on Earth we are free to define and measure latitude and longitude. Latitude is based on the positions of the North Pole and the South Pole and these are not arbitrary points. Given the definitions of "degree", "minute" and "second" as angular measures, the approximate latitude can be easily determined by looking at the North Star with a sextant. It is even possible to build a simple closed box, (containing a gyroscope as a gyrocompass along with a microprocessor) which can always know its latitude without any external data. On the other hand, determining longitude by celestial navigation needs both the selection of an arbitrary reference point on Earth, (the Greenwich observatory) along with the knowledge of the Earth's angular orientation (obtained by celestial sightings with a sextant to get elevation angles of navigational stars) and the date and time of day or the sidereal time.

Living with the restrictions of the theory of relativity is like living in a world where everyone has his own standard as to what a second is and what a meter is. Of course, under almost all circumstance the local standard actually makes far more sense than an absolute standard. If we want to boil a 5-minute egg on our spaceship and we time it with UITC using an AT-Clock, we might find it still raw since only a few seconds of local cooking time might have corresponded to 5 minutes of UITC time. We don't want to propose that everyone switch to absolute time. We want everyone to know that physics in no way prohibits us from knowing absolute time or from building clocks that keep absolute time or building absolute tape measures and absolute speedometers and absolute 3D compasses. The ability to detect absolute motion is a part of physics. This fact is distinguished from the question as to whether there is a single, universal preferred reference frame, (as is more or less true for latitude) or whether we need to arbitrarily establish one (as is true for longitude). In a sense, the AT-Clock as a part of physics means that there is an exception to the so-called-law that from within a closed system, we cannot distinguish one unaccelerated reference frame from another. That so-called law is true for almost everything -- but AT-Clocks are exceptions. In that sense, the AT-Clock is the K^0 of translational invariance!

Finally, we have already discovered an absolute reference frame, the Cosmic Background Radiation. Our measurements of it are terribly imprecise, but there is no reason why that should remain the case. New technology ought to allow for greater and greater precision in measuring the velocity vector of our solar system with respect to the CBR.

We now wish to examine, in great detail, questions raised by Newton and Mach with regard to reference frames. To simplify our thoughts, we can imagine our experiments in a region without complicating gravitational fields. We observe that experiments have so far shown the following:

The Michelson-Morley experiment (and many subsequent experiments) gave negative results when attempting to detect the Earth's motion through an absolute reference frame. (A possible exception is the CBR anisotropy)

Linear acceleration is easily detected and measured.

There is no experimental evidence that supports the existence of absolute angular orientation.

Angular rotation is easily detected and measured.

This results in a paradox. How can there be absolute acceleration without a reference frame? The same observation is true about angular rotation, as observed and commented on by Newton. We can use the Digital Perspective to reexamine why Mach felt that inertia needed the "fixed stars" as a reference frame. There are two contrasting views about matter in space.

One view is that empty space is nothing and that it makes no sense to speak of it. That view takes the position that concepts such as distance and velocity are only possible if there are objects in space and that those objects are what creates the properties we think of as distance and velocity. Today, there are very few people who still cling to the notion that there is such a thing as empty space; equivalent to *nothing* and of which we cannot speak.

The view of modern physics sees space as complex and having definite properties. A volume of "empty space" is capable of promoting a pair of particles out of the vacuum. Such a pair of particles have intrinsic length properties that can be measured. Therefore we must assume that there is no physical space that is devoid of the concept of absolute length.

The main point is that something about Newtonian relativity, inertia, absolute linear acceleration, angular anisotropy and absolute rotation seems out of whack if there are no absolute measures of space and time. Obviously, Einstein's theories brought a great deal of consistency to the situation but did not resolve all the issues. That uncomfortable feeling could not be well formalized because at the root, it is an informational problem and until recently there was no familiarity with such things.

Consider a closed, isolated system with 6 Newtonian particles in rectilinear motion with respect to each other. We assume that they all started their motion from approximately the same point and particle 1 is going East, particle 2 Down, 3 South, 4 West, 5 Up and 6 North. We can set up a 3D coordinate system with an origin at the center of mass of the 6 particles, and aligned so that the axes are coincident with the lines of motion of the particles. We can measure their positions relative to the coordinate system or relative to each other. We can measure their momenta. This is meant to be simple and straightforward with no tricks or hidden complexities. We assume no changing internal states. We ignore for the time being, all forces such as gravitational.

Associated with each particle are several kinds of information.

Which kind of particle is it? What is the internal state of the particle? We wish to simply use "state" to differentiate various kinds of particles. State might include "lepton", "generation 1 (electron)", "negative charge state" etc. The amount of information related to these question is $\log_2 N$, where N is the number of different kinds of answers there might have been (given n equally probable states). A better measure would be the number of "yes" or "no" questions that would have to be asked (of some oracle) in order to correctly determine particle state. Given the state, we will assume that we know the particle's rest mass.

The particle's spin state with respect to some particular direction.

Where is it (at a given time)?

What is its momentum? We choose to think about momentum instead of velocity because we believe that the informational representation of the movement of a particle is in terms of its momentum.

We can ask questions about the information such as "How many bits of position information is represented by the particle's position?" The simplest such question is with regard to the information associated with spin. If we pick a direction and then test as to what the particle's spin is with respect to that direction, we always get exactly one bit of information ("up" or "down")! However, we can measure many bits of position information and many bits of momentum information. In some theoretical sense, once we have our coordinate system, we can continue to measure the position information and the momentum information as the system evolves. What we are describing is a process that evolves over time. A modern understanding of the informational viewpoint requires us to assume that somewhere, somehow there is an explicit form of the information that can be measured. If the position information that we can measure can change, then there must be the equivalent of an informational process that, in effect, changes the positional information. If the particles accelerate, then there must be an informational process that, in effect, changes the momentum information.

Finite Nature and Relativity

We assume the Finite Nature Hypothesis and examine the consequences to Einstein's Theory of Relativity.

DM is a model of physics that assume space-time is an unusual kind of Cellular Automata (CA). A simple CA is a Cartesian lattice where each point on the lattice is called a cell, and each cell is always in one of a small number of states. The state of a cell can always be represented by a small integer. There is a clock that tick once per unit of time. Between ticks, nothing happens. At each tick, cells transition to new states depending on the *rule*. A typical *rule* is a list of possible states of a neighborhood of cells around the given cell. For each possible state of the neighborhood, there is an associated state to be assigned to the cell. Of course, the cell might also be part of the neighborhood. The kind of CA we are proposing for DM is a RUCA (Reversible Universal Cellular Automata) that is unusual in a number of ways.

There is one simple concept that is the key to being able to understand how it is that a Cartesian cellular automata (CA) can correctly model physics. This has to do with the nature of a Universal Computer. The word "Universal" implies that a computer can do anything that any other computer can do. However simple a RUCA might be, it is Universal and can compute anything that can be computed. As a trivial example, it could be programmed with the mathematical laws of special or general relativity. While it is not necessary for every DM model to be based on a Cartesian lattice RUCA, we have many reasons to suspect that such models are most appropriate.

The first concept to get straight is that the cellular space of the RUCA is **not** the space of the physics modeled by the RUCA. It is the space of the computation. This bears repetition. **The cellular space of the RUCA is not the space of the physics modeled by the CA.** If the space of physics is not Cartesian, that in no way disqualifies a RUCA based on a Cartesian lattice from being a perfectly accurate model of physics. There is no problem for the space of the RUCA to be a simple Cartesian lattice while the space of the simulated physics is relativistically correct; for both Special and General Relativity. Of course, it is convenient for the space of the RUCA to be similar to the space of physics. Topologically, a Cartesian space-time lattice and a relativistically correct space-time lattice are topologically similar. The local neighborhood of one maps into the local neighborhood of the other. In the absence of strong gravitational effects, geodesics[23] in both have similar properties. However, one needs to appreciate the power of a Universal Computer. Every Universal Cellular Automata (UCA) can exactly simulate any kind of space. The simulated space could have 26 dimensions, wormholes, and any kinds of distortions that one can program. It should be obvious that a UCA can be programmed so that its locally Cartesian space is Relativistically correct with regard to the effects of gravitational and acceleration effects on geodesics.

In a sense, the character of the space of a CA has similarities with the character of the space of Random Access Memory Chips that all modern computers use. Basically, RAM chips are 2 dimensional structures. This does not mean that a computer can only simulate 2 dimensional physics. We can calculate what kind of path a free particle will take, given gravitational fields strong enough to require the mathematics of General Relativity. In a UCA model of physics, we can send a free particle on its way and see what kind of path it takes. Naturally we expect the UCA model to agree with the accepted mathematical model of physics. The only reason it wouldn’t is if we had designed the UCA incompetently. But if finite nature is true, there’s not only an exactly correct UCA model, there’s an infinite number of exactly correct UCA models. That is a consequence of the fact that there are an infinite number of possible Universal Computers.

We believe that there will be found, efficient UCA models that retain the neighborhood locality match with the space of physics while at the same time being Relativistically correct. Universality guarantees the possibility of being relativistically correct; however we do not believe that a good model of DM will require any such programs to be explicit. There is no reason to assume that some law of nature or mathematics stands in the way. Much progress has been made, and reported in the literature concerning CA’s that can be Relativistically Correct. (Tomasso Toffoli can give references.)

[23] A path followed by a free particle, such as a photon, traveling through space. It is normally what we would call a straight line, but gravitational effects can change the properties of space so as to curve the path of a photon.

The Relativity of Simultaneity

Einstein, in his book Relativity, Chapter IX, The Relativity of Simultaneity, wrote an excellent layman's description of this concept. While the first edition was published in 1916, Einstein added Appendix V, Relativity and the Problem of Space, to the 16^{th} edition published in 1952. His explanations of the problem of Simultaneity are lucid and easy to understand. What he describes are two methods of judging the simultaneity of two lightning strokes; one by an observer on a moving train and the other by an observer on a stationary embankment. He then proceeds to show that using a particular method of judging, one observer would claim the lightning strokes to be simultaneous while the other would not. The point of this observation is to conclude that there is no method or standards that would allow all observers to agree about the ordering of various events. We will argue the opposite.

The problem with Einstein's *gedanken* experiment is that it's also easy for each observer to make local measurements that allow the calculation of what the other would claim. The observer in the train can easily measure that the observer on the embankment would see the strokes as simultaneous. All that is needed is to measure both the local times of the 2 observed strokes, and the doppler shifts in the spectrums of the 2 strokes. This, along with knowledge of physics allows for the calculation of the simultaneity from various viewpoints. Thus we are still left with the possibility of different conclusions as to whether or not two events occur simultaneously, but we are not left with the necessity of the possible confusion. Just as we can define a standard meter, kilogram and *second*, just as we can define UTC, we can define a standard space-time metric that everyone can use.

When the metric standard of mass was defined as the kilogram, it was not known as to whether or not the atomic theory was correct. However, the fact that we could create an arbitrary standard of mass, and communicate this standard to others, hinted at the possibility that certain naturally occurring objects might all have exactly the same rest mass (such as atoms of $Carbon_{12}$ in the ground state). Thus, as it turned out, there are absolute, universal standards of mass. In the early days of constructing clocks, it was clear that our standards of time were arbitrarily related to the rotation of the Earth, vis-·-vis the sun. Today we build very accurate clocks based upon universal qualities of atoms. It would be easy to communicate to aliens, by radio, our current standards of Mass, Length and Time. On the other hand, we believe that we currently have no way of communicating what time it is (intergalactic time and date) in an unambiguous way. We will attempt to show that this need not be the case for long. The ideal zero point for a universal time-date is the moment of the big-bang. Currently we only know that moment with an enormous error band of billions of years! If we discover a highly accurate way of computing the time since the big bang, we might be able to know the absolute time.

What we can do is to set our universe time-date clocks by referencing them to major extra-galactic events such as super nova explosions or Gamma Ray Bursters (GRBs). Sanduleak -69◇202 (SN1987A), a spectacular super nova explosion (that occurred about 170,000 years ago in the Large Magellanic Cloud) gives us a chance to define a point in space-time with reasonable accuracy. While we do not know where SN1987 was, within a range of tens of thousands of light years, we do know where we were and when it was when we first detected SN1987A. On February 23, 1987, at 07 hours, 35 minutes and 41.37 seconds UTC (Universal Coordinated Time) the first of a small number of detected neutrinos, most likely from SN 1987A arrived on Earth. Strangely enough, we could communicate to a distant alien an unambiguous reference to some time and date on Earth by doing the following: We define the second based on the physics of an atomic clock, then we can reference SN1987A along with a number (at least 4, but probably many more would be useful) of other similar extra-galactic events such as notable GRB events, giving our data on them. We also need to explain where the Solar System is and its velocity, along with the Earth's orbital parameters. Another method of informing potentially hungry aliens as to where we are (their next meal?) was developed and launched with the Pioneer 10 space-craft. It had a chart of nearby pulsars, identifiable by their pulse rates (with a picture of a Hydrogen atom, along with numbers, to indicate the standard of time). Future generations of engineers at NASA may design a mission to launch a probe to catch up with Pioneer 10 and bring it back to Earth! With all such things, some alien race (that is just a little bit smarter than us and that already knows where SN1987A and various GRBs were with fairly high accuracy, ought to be able to synchronize clocks with us to within a small fraction of a second! It is even possible to effectively send letters to unspecified alien races on distant planets, so as to tell them when we sent the letter, without tipping our hand as to where we are. This involves giving the times of various interesting galactic events as would be observed from some very distant place. This allows them to do the time calculation without giving away our location. In such cases we would have to be careful to not over specify the time by giving more than the minimum amount of information, as second order circumstances (intervening gas clouds or gravitational effects) might allow a clever alien race to see through our attempts to hide our location.

What Time Is It?

We shall proceed in 3 steps. First, our task is to examine aspects of our present understanding of fundamental ideas in physics that lie beyond what can be concluded with mathematical rigor. Second, we will try to explain new realizations that must affect our picture of the world. These involve thought experiments that could be replaced by real experiments. Third and finally, we wish to make a convincing case for replacing some of the most cherished ideas in physics with strange and unfamiliar substitutes.

What we will not do is show you data from old experiments. No data from new, conventional physics experiments. No new mathematical laws (the old ones are fine, they just don't mean what we used to think they meant).

Instead I will argue in English, using various kinds of Gedanken experiments as examples, (and in light of new knowledge) so as to try to convince the reader that when others (including Einstein) did that, they sometimes came to wrong conclusions. Of course, our method is exactly what others have done in the past.

The first example is about the relativity of simultaneity.

Unfortunately, something as simple as knowing what time it is, is complicated by certain facts of physics along with societal demands. It would be highly desirable if we (everyone on Earth) could at least agree on what time it is. Unfortunately we can't. We have decided to divide the world up into time zones so that for most people the sun usually rises in the morning hours (6 AM ±) and usually sets in the evening hours (6 PM ±), depending on where you are and on what season it is. What we have done is to come up with a very precise standard called UTC, which is approximately equivalent to the ordinary concept of what time it is in the village of Greenwich , England. Once we have the definition of UTC, we can, by means of simple formulae and a marked up map of time zones, calculate the local time for various locales and seasons.

In the old Soviet Union, which spanned 11 time zones, all the train schedules for the whole USSR were published in Moscow time. This was most convenient for the rulers of that society. Pilots, the world around, refer to UTC (Universal Coordinated Time, but the letters for UTC come from the French!) They need to do so for many reasons including the fact that aircraft can cross one time zone every few minutes as they pass near the North Pole. What we have been able to standardize is on the unit of time, the Second. The definition of the Second has had a similar evolution. Starting out as about the same as the resting pulse rate of a reasonably athletic adult, it was eventually defined as: 1/60 of a minute, which is 1/60 of an hour, which is 1/24 of a day; 60 x 60 x 24 =86,400 seconds per solar day. There is still confusion. The year 2000 version of a very popular encyclopedia claims:

The second, the basic unit of time, was defined as 1/86,400 of a mean solar day (*see* Day) or one complete rotation of the earth on its axis. [24]

They get it right and they get it wrong, all in one sentence; it should be "…or about 361 degrees of rotation of the earth on its axis." A mean solar day is more than one complete rotation of the earth on its axis.

Further, as we learned to make ever more accurate clocks, we discovered that the Earth is slowing down! This might have meant that UTC would slowly drift away from solar time so that at in the future, the sun might not rise up at Greenwich until noon! The ad hoc solution to that problem is that the time lords of UTC announce every so often that they are going to insert a "leap second" into UTC to slow down the passage of UTC days so as to keep UTC in synchronism with the solar rotation of the Earth. At this point, questions like "What time is it?" or tasks like timing a 5 minute egg do not bother us very much. However, if we want to

[24]"International System of Units," *Microsoft® Encarta® Encyclopedia 2000.* © 1993-1999 Microsoft Corporation. All rights reserved.

understand exactly what, in principle, is going on about the time of day and about the timing of a 5 minute egg, things are more complicated.

The time and *the passage of time* are complicated in other ways, as was discovered by Einstein almost 100 years ago. We are going to examine *the time* and the passage of time very carefully, in order to go one step beyond present concepts just as UTC and the definition of the Second go beyond the more informal concepts of *the time* and of *the passage of time* that existed in 1735 when John Harrison invented the Chronometer.

Imagine a society that only had simple pendulum clocks, and no other method of telling time. Their clocks might run slower on warm days (as the bar supporting the pendulum bob expanded) and faster on cold days. They might start out having many strange theories about the relationship between time and temperature. Eventually they would figure it out and learn to build more accurate clocks.

Absolute Time Clocks

We must digress to give a definition of Absolute Time and then give a design for building clocks that keep Absolute Time correctly (AT-Clocks). What we will be describing is how, in principal, to build AT-Clocks. Thus, we define clocks that should work properly for trips to distant galaxies traveling extremely close to the speed of light and perilously close to massive black holes. While no one has ever built an AT-Clock, there is no doubt whatsoever as to the practicality and physical correctness of the design.

We propose to construct a master AT-Clock that defines UITC (Universal Intergalactic Time and spatial Coordinates). This master AT-Clock can be located anywhere, such as in Boulder Colorado USA where clocks that accurately broadcast UTC are located.

An AT-Clock would be somewhat similar to the existing clocks but would operate on different principlels. The core of an accurate AT-Clock is an ordinary accurate atomic clock. A computer reads the output the clock. The computer is also connected to an accurate INS (Inertial Navigation System) similar to what is used in aircraft, missiles and submarines. We would like the INS used in AT-Clocks to be of greater accuracy then current models, but that is a matter of engineering; no laws of physics stand in the way of improvements. UITC, once defined, would drift away from UTC since it would not be based on the rate of the Earth's rotation.

What we want is for UITC time to be defined as the time that would be kept by an isolated clock, isolated from nearby gravitational and all other effects, co-located and co-moving with the approximate center of mass of the Universe. A particular spot would be picked out, a coordinate system laid out, and then we would define UITC). To set an AT-Clock it must know much more than the time and its spatial coordinates. Here is a list of the data structures that constitutes UITC and which every AT-Clock would need:

Absolute time (t)

Absolute spatial position coordinates (x, y, z) relative to a carefully defined point somewhere near the estimated center of mass of the universe

Absolute angular orientation coordinates (ρ, θ, ϕ)

Absolute spatial velocity coordinates ($\dot{x}$, $\dot{y}$, $\dot{z}$) , defined by 4 extra-galactic references.

Absolute spatial acceleration coordinates ($\ddot{x}$, $\ddot{y}$, $\ddot{z}$)

The Gravitational Tensor

Procedures that can calculate from various sensors, using physically correct mathematical formulae that keep the coordinates current. Further, a record of the trajectory of the AT-Clock is kept in the memory of the clock. Thus, all AT-locks must use identical assumptions for the intergalactic geographical and temporal facts about our galaxy, our solar system, Earth, Boulder and the Master AT-Clock. What would be true is that our assumed position of the Center of Mass of the Universe and of the instant of the Big Bang would be gross approximations, but that would not affect the accuracy of how our AT-Clocks would work, as all of them would be making the same assumptions.

While we are mainly interested in the time, each AT-Clock will also know its position, velocity and orientation (in UITC coordinates). What an INS works from are direct measurements of linear acceleration and the velocity of angular rotation. These measures are accurately integrated and kept track of in order to compute linear velocity and position along with angular orientation. Systems dealing with such measures as linear acceleration or angular velocity that are continuously integrated could have the nasty property of also integrating errors that grow without bounds. However, there are also ways to make external measurements, such as is done in celestial navigation that can essentially nullify the effects of integrated errors.

Once synchronized to a Master AT-Clock, each AT-Clock use its INS and computer to keep track of its entire trajectory. It would know where it is, its orientation, its velocity and the history of its trajectory. The clock would be able to measure the acceleration vector and computationally separate it from the gravitational tensor. As for gravity, it would have to have a detailed library of known gravitational facts (such as the masses and orbits of the sun, planets and nearby stars). It should also be able to make sufficient gravitational measurements of gravity gradients in order to compute the complete gravitational tensor. Such computations rely on a known starting state, and continuous measurement and computation involving the entire history (space-time trajectory) from the known initial state. The advanced models should be able to add to their library the facts about new gravitational objects that are encountered and measured during various journeys.

This information, using the known laws of physics, is used to compute the corrections to the basic measurement in order to show on the face of the clock what would be shown on the face of the Master AT-Clock. In addition, each AT-Clock could also show UTC and local reference frame time. The spatial coordinate system in AT-Clocks would be taking into account the motions of the galaxy, the solar system, the planet Earth and the rotation and other motions of the of the Earth and finally any motion on the Earth of the AT-Clock. All effects due to gravity, linear acceleration and velocity, along with angular motion, would also be known and taken into account in computing times, position, velocity and orientation.

Synchronization of AT Clocks 1

AT-Clocks can be synchronized with UITC so that they always show the correct UITC time on their face. What we will try to explain is that the reason Einstein's clocks don't allow for the determination of absolute simultaneity has nothing to do with the laws of physics. All that one needs is a definition of absolute simultaneity and knowledge about AT-Clocks! It's also related to our defining *absolute time* and a *preferred coordinate system*. While we choose a particular preferred coordinate system, if we do it competently we can assume that others in distant galaxies could choose a similar one, just as every isolated primitive society on Earth had approximately similar concepts of time for the day, the month (phases of the moon) and the year.

There is nothing wrong with Einstein's analysis of what cannot be done with ordinary clocks. However, there is nothing in Einstein's theories that rules out building extraordinary clocks; AT Clocks.

To understand the problem one must admit of the possibility of a solution. We have been told that during a trip in a relativistic spaceship, ordinary clocks on the spaceship will not keep time with the ordinary clocks at home (UTC). Let us assume that the spaceship takes off from the Earth at 1200hrs, September 22, 2018 UTC. Because of the trip trajectory of the spaceship, its clocks (and computers) are running slower than the UTC clocks. Assume that when my spaceship clock shows 0900hrs (9:00AM), October 2nd, 2020, the ordinary clocks at home show 1000hrs, October 2nd, 2020 UTC. Time has slowed down on the spaceship. We all have to agree that this is the case, it's just the consequences of Special Relativity. What is a little bit more subtle is the question: is there something the spaceship clock could show on its face so that we would all agree that it was keeping time with UTC?

We should be able to agree that if it showed 1200hrs, September 22, 2018 then it is definitely too slow. And if it showed 1200hrs, January 1, 2022 then it is definitely too fast. We then have good reason to believe that we can agree that there is a time, somewhere in between too fast and too slow (within some small increment, such as within 1 second) which can be defined as the time to be shown on the spaceship clock that is defined the same as UTC.

Each AT clock also comes with a built in digital tape measure. It has 2 digital readouts: one gives ordinary tape measure distance that shrinks appropriately at relativistic speeds while the other gives measurements with no shrinkage in the direction of relativistic motion; it lets us measure how much other objects have shrunk. The AT-Clock does 2 additional things: allows the synchronization of any number of clocks, and keeps time in such a manner as to result in no relativistically caused difference in any subsequent resynchronization. What we mean by no difference is not that the clocks are infinitely accurate, but that the errors are no more than they would be for ordinary good clocks that are always in the same inertial system.

We know that early pendulum clocks ran slower on hot days, because the length of the pendulum increased with temperature. This was easy to design around. We know that pendulum clocks that keeps good time at sea level run slower at high altitude because of the decrease in the strength of gravity. This is also easy to correct. Similarly, an AT-Clock can be designed to correct for every effect we know of so long as we understand the process that causes the effect.

Synchronization of AT Clocks 2

Here are a number of ways to synchronize an AT-Clock to UITC so that it has the correct, unambiguous and absolute time and spatial coordinates, velocity vector, angular orientation, spatial acceleration and gravitational tensor.

It can be brought to Boulder, set next to the Master AT-Clock and simply synchronized to the same time. (All other internal parameters having to do with position, velocity and orientation and gravitational library also need to be synchronized).

It can be brought next to any working AT-Clock, brought into the same inertial reference frame, and synchronized to that clock, which will bring it into synchronization with the master AT-Clock.

It can pass near another AT-Clock while not in the same inertial frame. By communicating with the other AT-Clock, it can learn enough to synchronize itself so that if it were brought into contact and same inertial frame, it would already have the correct time and correct set of other parameters.

It can also synchronize itself without ever being in the same inertial frame as any other AT-Clock! Say our spaceship was struck by an intergalactic lightning bolt and lost all track of time. It needs to not only synchronize its own master clock to UITC time, but it must set all of the clocks other variables properly so that the clock continues to keep correct UITC. We assume that the ship is not going to come to rest in any inertial reference frame with an AT-Clock for a long time. Here is what it can do. It makes a reasonable assumption as to what is the correct UITC and sets its own master clock to that time. Of course it also has to make assumptions for all the other state information it's master clock needs (ships position, orientation and velocity). It then synchronizes a secondary AT-Clock to exactly match the entire new state of the ship's master clock. The ship then launches its secondary AT-Clock to rendezvous with the nearest source of UITC. Once there, (and in the same inertial frame) a computation is performed involving the data in the secondary AT-Clock and the local AT-Clock that has the correct UITC. A message can be composed and sent by radio to the spaceship with information that will allow it to compute everything necessary to bring it's master AT-Clock into exact synchronization with UITC. The reason that this is possible is that AT-Clocks retain the effects of entire trajectories and can compute or recompute all the relativistic effects.

Synchronization might also be possible by exchanging signals with 4 non-coplanar AT-Clocks that each have correct UITC. To some extent, the Doppler effect can be used to compute the relative closing rate to each of the 4 AT-Clocks allowing a determination of velocity and distance. There are circumstances where this method might fail.

Synchronization can also be done in a manner similar to how the GPS (Global Positioning System) works. This is accomplished by having many widely scattered AT-Clocks each transmitting UITC, and all other necessary parameters. In this case, simply receiving and analyzing data and signals from at least 4 reasonably located AT-Clocks would allow for synchronization. The data would have to include a map of all intervening significant gravitational objects.

There are lots of other ways to do the space-time synchronization; it's merely an exercise in the laws of physics and the possible roles of information in physics. The details of such other methods of synchronization are left as problems for others.

The Clocks Back Home

Now we want to deal with interpretations of the laws of relativity. As recorded in Lectures on Physics, Volume I, Chapter 15 (The Special Theory of Relativity) page 6, after describing a "light clock" that keeps time by sending light pulses back and forth, Feynman said to his students :

"Not only does this particular kind of clock run more slowly, but if the theory of relativity is correct, any other clock, operating on any principle whatsoever, would also appear to run slower, and in the same proportion -- we can say this without further analysis. Why is this so?…"

Then, after Feynman describes some other bases for keeping time, he continues.

"…Perhaps *this* clock will not run slower, but will continue to keep the same time as its stationary counterpart, and thus disagree with the other moving clock. Ah no, if that should happen, the man in the ship could use this mismatch between his two clocks to determine the speed of his ship, which we have been supposing is impossible. *We need not know anything about the machinery* of the new clock that might cause the effect--we simply know that whatever the reason, it will appear to run slow, just like the first one."

To Feynman's great credit, after assuring me that the above quote was "…absolutely correct…", it took him less than 3 seconds after I hinted at the design of an AT-Clock to state that everything in the above quote was "…absolutely wrong…". In another 30 seconds he explained that:

We have experimental data, which is correct.

We derive mathematical laws and equations (The Theory of Relativity) that are accurate and correct.

The way we arrive at English Language pronouncements that elaborate on the consequences of the correct mathematical laws is a "…dippy process…"; which was dead wrong in this case.

The design for an AT-Clock

The AT-Clock is programmed with valid formulae that correct for the slowing down that would be caused by relativistic effects; the clock can always display on its face the same time as shown on the Master UITC clock along with local spaceship time and UTC (the time back home). When we say that an AT-Clock has the correct time, this is true even though the computer itself is slowing down. Of course the men in the spaceship will be able to know the speed and position and orientation of the ship! Why not? Pilots have been flying for decades with inertial navigation systems and they know the speed, position and orientation of their ships!

More AT Clock

We now will return to the AT-Clock. We must recognize that even though it is a complex product of human ingenuity, it is still a part of physics. Let us assume that all the AT-Clocks in existence have been synchronized to one master AT-Clock. One can do physics experiments on these AT-Clocks as though they were some new kind of particle. These experiments would make it clear that insofar as AT-Clocks are concerned, there is a preferred, fixed coordinate system. Using AT-Clocks allows for a universal standard of time that allows for the definition and measurement of UITC from any reference frame. It would be a simple matter to determine if 2 separated events occurred simultaneously in UITC. A new Michelson-Morley type experiment, to measure speed through the ether, (as defined by zero velocity in UITC space-time coordinates) would be easy, using an AT-Clock, and would give a positive result. The measurements would clearly show the Earth's rotation, the orbital speed of the Earth going around the sun, the speed of the Solar System orbiting the galactic center, the speed of the galaxy in the grip of the galactic group and finally the whole group hurtling away from the Universe center of mass.

Pilots and air traffic controllers use GMT (Greenwich Mean Time) for flight plans but plan dinner dates according to the local time zone such as EDT (Eastern Daylight Time). UITC is good for a few things but local, ordinary clocks are better for most things. The math of physics using UITC is different and sometimes might be the preferred approach. In any case, the fact that we can build and synchronize AT-Clocks does not make the experiments we can conduct with them any different, in principal, than experiments at CERN using the LEP or LHC.

At one time, Relativity and Quantum Mechanics were not a part of physics. The leap to incorporating the informational point of view into physics is even bigger and less intuitive than the leap to Relativity and QM. The reason is simple and obvious, there are no revolutionary results from physics experiments at this time that compel one to make the leap. Just try to imagine someone trying to sell the scientific community on Relativity and Quantum Mechanics in 1720 (so that Newton could incorporate it in the 3rd edition of the Principia!). Imagine some poor alien soul, stranded on Earth, trying to get Newton or Leibniz to accept everything we now know about modern physics, including QCD. Today, the attitude of modern science is that views need not change until and unless there is new experimental data that forces the change. This attitude has made perfect sense up till now. There is no shortage of crackpots trying to sell crackpot ideas. The best filter, necessary to keep all working scientists from wasting too much of their time, is the test of a verifiable and repeatable experiment that requires one to adopt new views. While I have tried to sell the idea of considering AT-Clocks as a particle subject to physical law, it's a hard sell. I doubt that many will buy into it for a long time despite my absolute confidence that eventually the necessity of a coordinate system will be understood. Of course, if and when we develop some new technology that can measure it (as the CBR anisotropy does very grossly) then acceptance will follow. Consequently the Fourth Law, if it happens to be true, may not likely come into vogue for some time!

To be continued…!!!

Can we build a set of artificial billiard balls that do not obey the laws of physics? Can we observe them in experiments and conclude that for these special balls, conservation of momentum is not valid? The answer is "No!" It's no different than trying to build a *perpetual motion machine* that continually makes available energy while not using anything up. Thus a *perpetual motion machine* purports to violate conservation of energy. If you didn't know about nuclear energy, you might believe that a device powered by a radioactive power source was a perpetual motion machine. But, that would only be because of ignorance of a very good power source.

Now, we can make unusual balls that seem to violate conservation of momentum and energy. Say the ball is hollow, like a basketball, and inside of it is a small radio controlled battery powered car. Then, if the car starts to drive (inside of the hollow ball) the ball can autonomously start rolling, change direction without bumping into anything and even roll uphill without slowing down. Thus, if we assumed that the ball was solid and of uniform construction it would appear to be violating the laws of physics. However, all it takes is closer inspection to understand the trick and to see where and how both momentum and energy are still conserved.

The AT-Clock is not a trick. If building a spaceship clock that keeps time with the clocks back home is forbidden by a law of physics, if physics forbids the astronauts from knowing the speed of their ship, then all the tricks in the world won't help. The truth is that it is not forbidden by a law of physics. It's just that for a long time, no one thought about how to define simultaneity and clocks so that there would be a sensible way to order events in different reference frames. Of course simultaneity has, so far, not been defined in ways useful for observers in different inertial frames. But it can be, through the use of AT-Clocks that while in different inertial frames, all keep time relative to a single reference frame.

Absolute Time and Absolute Position

In DM, the concepts of absolute time and absolute position make perfect sense. Once we know the units of time and length, and once we know the local orientation of the cellular array we have the possibility of determining absolute time and position. A logical point for the origin is the center of mass-energy of the Universe. As long as we cannot determine the origin with accuracy, we can define a single, universal and convenient, space-time origin.

How DM made progress

Having settled on the Cellular Automata as the model, there were a number non-physics like characteristics that had to be overcome. A list of CA deficiencies was produced. These had to be overcome before it would be possible to make a serious model of physics.

We know that Physics is Computation Universal. The only Universal CA known at the time was the Von Neumann model, a baroque system with 23 states per cell and all kinds of ad hoc characteristics attuned to modeling a Turing Machine that could grow a tape into empty space. For example, each cell, in essence, knew its left from its right.

One of the very few who followed and encouraged this work was Marvin Minsky. Sometime around 1960, he issued a challenge to find a rule that showed spherical propagation. Up untill that time, all known rules either had simple linear growth, like the tape in the Von Neumann CA or had structures that grew out in the form of a square (or a diamond) or some other pattern. No one had seen the spherical propagation that is so common in physics.

The fact that no one knew of a universal reversible CA was another problem. Microscopic physics is reversible. It may be CPT (Charge, Parity, Time) reversibility but reversibility is a very fundamental part of physics. There was no way to gloss over this problem. Everyone had heard that someone had a proof that a reversible system could not be universal. That made no sense that fact-rumor was ignored.

Then there was the question of a simple system with particles that could move in different directions. We thought that it might be possible to find such a system as an existence proof of a CA with particles.

The Search for Simple UCAs

Feynmans comments,

Digital Logic is the theoretical model of computer circuits. It is fascinating because the theoretical model and the actual circuits correspond to each other more perfectly than anything else. One day around 197X, an MIT graduate student, Roger Banks, was having a discussion with the author (his thesis supervisor)[i]. They were talking about the problem of finding a Universal Turing Machine simpler than existing models. Codd, in his Doctoral Theses had done a great job of reducing the complexity from von Neumann's 23 states to just 8 states. Codd's thesis had a *proof* that purported to prove that 2 states was not possible. Suddenly the author had the insight that one should have the CA model wires and logic gates instead of a Turing Machine. With wires and logic gates, you can wire up a general purpose Universal Computer. This reduced the problem to something much simpler. All that would be needed would be a way for some kind of signal to propagate, take a turn and be able to interact with another signal to do some simple logic function as does a transistor. The author went to the blackboard, fiddled around and soon came up with a 4 state system that was clearly universal. Both the author and Banks were very excited about this. The next morning both came into their Technology Square offices with a new Universal CA with 3 states per cell. It was determined that both had constructed essentially the same CA.

Banks decided to abandon his previous thesis project and do his Doctorate on Universal Cellular Automata. He decided to try to find a 2 state universal system. The author tried to discourage him because it seemed that there was little chance of finding such a system. Codd's thesis had a proof of the impossibility of a 2 state universal CA with a Von Neumann neighborhood. Nevertheless, Banks attacked this problem like a demon and in three weeks he proved the correctness of the advice "…little chance of success.". There was only a little chance of success and Banks had succeeded against the odds. Thus one more step was taken; a UCA could be extraordinarily simple; the Banks rule uses a von Neumann neighborhood (a center cell and the four neighbors, North, South, East, West and only 2 states per cell) and it is computation Universal. There has been no application yet for the Banks UCA but it forever laid to rest what had been an open question.

The Search for Moving Particles

Early research with CA quickly proved that any 2 dimensional CA with a 3x3 neighborhood was isomorphic to some more complex rule with a von Neumann neighborhood (where each cell has just 4 neighbors, North, East, South and West. For that reason it was decided to concentrate on nothing but the von Neumann neighborhood. This meant ignoring the popular 3x3 neighborhood. Lo and behold, John Conway, of Cambridge University invented the *Game of Life*. A wonderful CA with a 3x3 neighborhood that solved one of the problems on our list. The problem was this: Find a simple rule where as a consequence of the rule, there are particles that can move in different directions. The *Game of Life* had gliders, puffer engines and a whole zoo of particles that moved with varying velocities. It was a fantastic development. Conway posed a few questions about *Life* that he couldn't answer (he didn't use a computer!). At MIT, Gosper and others quickly found the answers to all his questions and found one other thing; using the MIT model of proving Universality by making computer logic and wires, it was shown that the game of life was Computation Universal. A key contribution was Gosper's discovery of the Glider Gun, a structure that emitted a steady stream of gliders, and a collision of a number of 18 gliders that resulted in the creation of a glider gun.

Some of the particles in The Game of Life were unstable and decayed. However, that process was deterministic, based on the state of the particle, while for real particles, the expected lifetime is always constant and independent of the age of the particle. This property gives rise to the characterization of unstable real particles by their *half life*. Further, the speed and direction of various particles in The Game of Life were all a consequence of the design of the particle. Despite those shortcomings, Conway's Game of Life provided support for the concept that very simple rules could show interesting, physics like behavior.

The Search for Reversible Computation

In 1974 I went to Caltech for a year, as a Fairchild Distinguished Scholar, with the intention of finding a model of reversible, universal computation. What I came up with was what I called "Conservative Logic". This was a reversible logic gate along with a concept of a wire that moved one bit of information somewhere in one unit of time. Together, these 2 elements allowed for the construction of reversible universal computers. After I returned to MIT, I and my students found that Conservative Logic could do everything we had hoped for. I also learned that Charles Bennett and Tomasso Toffoli had also come up with reversible models of computation. Charles Bennett showed that a reversible Turing machine could be constructed. Tomasso Toffoli showed that a reversible cellular automata could be constructed. Both these systems used the identical approach, they employed a method of remembering every single bit that might have been lost by storing those bits on a long tape. I had thought of the same idea many years before but rejected it because it wasn't esthetically pleasing. My main goal was a physics like system, and no one believes that the basis for reversibility in physics is that there is a tape recorder attached to every point in space. Conservative logic was the first model of Reversible computation that dispensed with the need to remember every lost bit until the end of the computation (the end of the computation doesn't occur in physics!).

I also embarked on a plan to find ways to convert various computational algorithms into reversible systems. This resulted in finding a general transform that can take programs (systems of difference equations) that implement systems of differential equations and convert them to a form where they are exactly reversible. This result was so counter intuitive that almost no one to whom the idea is explained can believes that it works. The reason is that as the computer is computing forwards, it continues to apparently lose information due to round off and truncation error. When you divide 1 by 3 you get 0.333333333…. If the computer has 20 digit numbers, then all of the infinite number of 3333333's after the 20^{th} 3 get thrown away. This seems to imply that it is impossible to exactly retrace your steps when going backwards, but the implication is simply false. The transform I discovered allows going backwards exactly, despite continuous round off and truncation errors both when going forwards and when going backwards!

My desire to work on DM found little support at MIT. For example, when I wanted to hire Tomasso Toffoli because of his work on CA, I was cautioned by an Associate Department Head "…don't you know that Cellular Automata is a dead field?" But at MIT as a Professor with funding, I was free to ignore this advice-warning and hire Toffoli anyway. Later, another highly placed member of the MIT faculty launched an attack on Conservative Logic. His argument was that there could not be a physically correct theoretical model of Conservative Logic because, he concluded, it had to violate the Second Law of Thermodynamics. He was certain that somewhere inside a Conservative Logic Gate, there had to be an element that could, in effect, convert random noise into useful energy. Rather than enter into an argument, I decided to find a physical model of reversible logic that was so straightforward and simple as to eliminate all questions about its needing to violate some law of physics. What I came up with is called the Billiard Ball Model (BBM) of Computation. It showed that all of computation could be modeled by a Newtonian system of perfect billiard balls set into very constrained motion and colliding with each other.

The Search for a Reversible Cellular Automata

At this point, we were missing one key development. We didn't have a suitable Reversible Universal CA (RUCA). Of course we knew of Toffoli's thesis (Tofolli had joined my group at MIT), but the idea of needing to dedicate a whole extra dimension, as the tape recorder, was too obnoxious to satisfy me. After the development of the Billiard Ball Model, my student, Norman Margolus, conceived of a wonderful CA rule and neighborhood, now known as the Margolus Neighborhood, and used it to implement a CA version of the BBM. At that point, we had solved every problem on my list of CA deficiencies. I later found a number of RUCAs that used ordinary CA rules as opposed to the Margolus Neighborhood

Meanwhile there was a minor resurgence of interest in CA's We (at MIT) did our best to promote interest in the field. Toffoli and Margolus collaborated on designing and producing a series of hardware CA systems that allowed a PC to emulate a CA at supercomputer speeds. Many interesting successes were obtained by those trying to model aspects of physical systems with CA. Examples include Nucleation, spin lattices, hydrodynamics… and many others. A company was formed to do what they called Digital Physics; they used a CA model of hydrodynamics as a competitor to PDE's (Partial Differential Equations).

CA's, Game of Life, Spherical Propagation, Universality, Reversibility, Conservation Laws.

Then find DM's that capture more

Analogues to energy, momentum, charge, etc.

Find mathematical models of physics that are closer to DM systems.

Some day find a correct DM model.

Quantum Mechanics and Digital Mechanics

It is interesting and informative to contrast Relativity and QM with DM. There is some commonality. All are alien to normal ways of thinking about things. While no one understands QM and only those trained in physics understand relativity, everyone can understand DM. Unfortunately, what I didn't know that the DM problem is more like the QM problem. To me, it seems like a big problem for one person. The ideas have taken too long to get to their present state. However, I firmly believe that some other person might have done the whole of DM, from nothing to getting it done, while I have merely moved from nothing to something. The most glaring problem has been the long periods of time when I could not figure out what to do next.

In 1957 I invented a simple storage concept called Trie Memory. I programmed it up on the Lincoln Labs IBM 709 computer. I asked around trying to find someone who could critique the idea. Several people told me that there was a young professor at MIT named John McCarthy who had similar ideas called "list structures". I decided to find McCarthy and talk to him. I was looking for him when I ran into him in the halls of Building 26 at MIT. I told him about Trie Memory standing there in the hall. While explaining the idea, John turned away and started walking slowly in the opposite direction. I kept on talking and he turned back and started walking towards me. He was simply pacing back and forth while I spoke. As he understood the idea and the fact that I had carried it forwards in terms of writing it up and simulating it on the 709, he got annoyed. "I've had essentially the same idea myself, but I never got around to writing it up. My reaction was one of elation. This was the first time that anyone whom I had great respect for, and who could understand exactly what I was talking about, verified to me that I had had a good idea. Why else would he be annoyed that he had never written it up? As things turned out, Trie Memory is nothing important. However, I got to know John and we became friends. After I came to BBM, I talked them into hiring John McCarthy and Marvin Minsky as consultants. We, along with my boss, J. C. R. Licklider all did lots of great things there! In 1958, I cautiously broached my ideas about DM to John McCarthy. I gave an example as to how gravity might appear in such a model. Today, the DM concept of gravity is very much like what I tried to describe to McCarthy, but vastly different from what McCarthy understood me to say. John had a response that I was to hear over and over again ever since:

"…yes, I've had a very similar idea…"

But then John went on to tell me his idea, and it was the idea of the big 709 in the sky. Something I had long since progressed beyond. John suggested that one might find out the word length and algorithm by carefully looking for roundoff and truncation errors in the results of physical experiments. The basic underpinning of John's concept and my original concepts were similar but only I took such thoughts seriously.

I asked John whether I should go on working on these ideas. He thought about it and said, "Yes." It's hard to explain the value to me, at that time, of any hint of support. On the other hand, perhaps the very nearly total lack of support is what has kept me going.

"Yes…" John repeated, "…the world is large enough that it can afford to have one person working on such ideas!"

I imagined physics as some kind of space-filling computational process that had algorithms that implemented electrodynamics. I thought that gravity might be the manifestation of some kind of roundoff or truncation process in the computation.

"Should I continue to work on DM?"

The Necessity of a Fixed Reference System

What we learn from physical experiments and the mathematical laws of Relativity is that any unaccelerated reference frame can be used to correctly express the physics of the motion of free particles. The observation that *any* such reference frame is equivalent to any other is usually taken to imply that there can be no absolute reference frame. If we knew that, for all time, no experiment would ever be able to detect an absolute reference frame, then there is nothing wrong with that belief. While Newton's laws of mechanics are correct, 1st order, we know now that they are but an approximation to the more general laws of Relativity. What DM implies is that the laws of Relativity are but a 1st order approximation to the processes of DM, which require a fixed reference system. We believe that if the Finite Nature assumption is true, then there ways will be found to experimentally measure absolute velocity and orientation with respect to the DM lattice. This will not mean that Relativity is wrong or irrelevant; just as Relativity did not mean that Newtonian mechanics is wrong or irrelevant. The precise experimental measurement of relativistic effects had to await various advances in technology. If Finite Nature is a true model then we expect that further advances in technology will allow for experimental measurements consistent with the DM theory. Like all good theories, DM lives or dies based on experimental verification.

Consider a free particle moving through some arbitrary reference system (translational motion). It has 3 degrees of freedom related to the x, y and z components of its velocity. While we may not happen to know the number, the number of possible states of such a particle and its reference system is large. Because of the Finite Nature assumption, whatever it is that might represent all the different states must discrete. What must be true is that there is something about the instantaneous state of the system that can be said to represent the information associated with the velocity. This implies that configurations of the states in the neighborhood of the particle have meaning that is associated with the velocity.

When a distant star turns into a supernova, it emits a large number of neutrinos in a short period of time. A number of such neutrinos have been detected here on Earth. What is clear is that detected neutrinos that have traveled independently arrive at about the same time. During most of the travel time, the neutrinos are relatively far from other matter, especially in the extragalactic regions of space. The inescapable implication is that there remains, in the vicinity of each neutrino, information whose meaning (and purpose) is making velocity information available to the process that causes the motion of the neutrino. Given any intergalactic reference system, there can always be an informational process that converts whatever information is used to guide the neutrino into x, y and z components relative to the reference system. Thus we have a situation where the information that guides the neutrino into following a geodesic (straight line) for perhaps millions of years, is equivalent to information relative to some intergalactic reference system. Consider many separate disconnected neutrinos traveling from the same supernova. There must be a process that converts each of the neutrinos' local velocity information into a common coordinate system for all of the neutrinos.

If there is no common reference system, what else could there be? Small regions of space could each have there own reference systems. Each region would have to make use of a process to keep track of the motion of its reference frame with respect to all neighboring reference frames. Further, the set of neighboring reference frames would change with time. This would also require a process that computed velocity coordinate transformations for the velocity information as the particle moved from one reference system to another. Why not accept Mach's principle? What is wrong with, on an intergalactic scale, the existence of a fixed reference system of some kind? The only reason to reject the concept is that we have tried to measure the Earth's motion through space by detecting the effects on light transmitted in different directions and failed. Further that failure led to the correct mathematical theory of Relativity. Nevertheless there is nothing in the mathematical Theory of Relativity that rules out the existence of a measurable fixed intergalactic reference frame. Our failure to detect the fixed reference frame up to now may be no more than a lack of imagination as to how to measure it. We must add that the assumption of the impossibility of a detectable fixed reference frame has been beneficial to progress in physics. The same might be said of the Caloric Theory, the indestructibility of atoms and of the concept of Conservation of Mass as an independent law. Having the wrong law (especially a conservation law) at the right time can be downright useful! Given Noether's theorem, we can think of the relativity of all unaccelerated reference frames as a conservation law. Well, in DM we start with the conservation laws. Momentum is just the vector sum of a number of momentum atoms that conserve momentum in a most basic sense. ****************************

Finally, consider Occam's Razor. No reference frame is an informational impossibility. A single common reference system is equivalent to a large collection of different reference systems, all inter-convertible into each other.

However the single reference system is a simple explanation while multiple reference systems are unnecessarily complex. In any case, either explanation would allow some kind of process to convert all the motion information to a common reference system. Thus every possible referencing system and the existence of a unique, natural fixed reference frame must be informational equivalents.

How might we measure the Reference Frame?

1. We know that, first order, the reference frame is hidden. Nevertheless, there may be extraordinarily sensitive techniques that might be able to detect and measure it. We shall propose a kind of experimental apparatus that might be able to measure both the angular orientation and the linear motion through the reference frame. This would be a piezo-electric crystal, similar to the type used in an accurate oscillator. It would have to be a single, essentially perfect crystal. The crystal would be placed in a container with a gas that could exert pressure on the crystal. The purpose of the pressure is to be able to control the inter-atom spacing of the crystal by modifying the pressure. This experiment would be a good one to conduct at the South Pole. There are 2 reasons. First, the translational motion of the South Pole (or North Pole) is simpler than for other points on Earth. Second, Maintaining a stable angular position is easier. These considerations need only apply until we know what we're doing. While the intellectual simplicity of the South pole is nice, it is also feasible to conduct the experiment anywhere. The expectation is that the electrical impedance seen by the circuit driving the crystal will change when all of the following constraints are met.
2. The orientation of the crystal lattice would have to be aligned to the reference system. It might not be necessary for the crystal to be cubic. Rather what is needed is that a sequence of crystal planes be aligned with the reference system planes throughout most of the crystal. This alignment needs to be very good, so that a sufficient fraction of all the atoms in the crystal are in the same phase, regarding plane alignment. The concept is that each distance between planes of the crystal would contain an integral number of planes of the DM substrate. This number will likely be a very large number. If one edge of the crystal is assumed fixed, the position of the other edge must be aligned to an accuracy of less than a fraction of a unit of length!. This is one the reason why the alignment would be easier for a smaller crystal. The fraction is approximately the reciprocal of the number of planes in the crystal.
3. Obviously, the experimental apparatus will have to be able to compensate, in various ways, for the motion of the laboratory. This calculation needs to take into account very precise details of the changing orientation and motion of the laboratory as the Earth rotates, and as the Earth-Moon system orbit around their common center of gravity, which orbits the Sun. It is conceivable the effects of other planets may have to be taken into account. Finally, moving masses near the experimental apparatus might need to be controlled or taken into consideration. Given assumptions as to the unit of length and the apparatus designed to detect absolute motion, it is not a difficult task to calculate what needs to be taken into account and what can be safely ignored. Of course, a laboratory could be located

in space, but the need to compensate for angular and translational motion would still persist, even in a true zero G environment.

4. It may make sense for the crystal to be quite small. The requirements for accuracy and precision on the angular orientation of the crystal are linearly related to the physical size (length) of the crystal. Decreasing the crystal size may decrease the signal to noise ratio of the detector.
5. The spacing, in the crystal, of the planes that are to be in physical synch with the planes in the reference system needs to be adjustable. This is the point of being able to adjust the pressure. In adjusting the size of the crystal, the range of adjustment needs to be sufficient so as to create a regular pattern between the planes of the crystal and the planes of the reference RUCA, when the two are aligned.
6. The crystal will be driven by an oscillator, far from the crystals resonant frequency. (It might be driven by being illuminated by a coherent light source), The object will be, to completely explore the space involving multiple orientations, units of length and units of time. At some frequency, which evenly divides the RUCA frequency there might be a resonant coupling between the oscillations in the crystal and the frequency of the RUCA. Since there is, in the DM model, a simple relationship between the unit of length and the unit of time, the frequency search could be delimited.
7. The expectation is that when the correct combination of angular orientation, lattice spacing and driving frequency are achieved, there will be a change in the electrical impedance or the optical characteristics of the crystal. Such experiments, if successful, should be able to accurately measure all of the parameters of the underlying reference system. There will most likely need to be a long search for the correct combination of parameters, but once they are known, it will be easy from that point on to lock onto the reference system very quickly.
8. If the crystal lattice spacing is 1 Angstrom (10^{-10} meter) and the crystal is a cube 1 micron on edge (10^{-6} meter) then there will be 10,000 planes in the crystal.
9. If the unit of length is 1 fermi (10^{-15} meter) then there will be about 100,000 units of length per crystal plane.
10. The total space to be explored is the product of the number of angles in each of ρ and θ (any ϕ is probably ok), the adjustment of the inter-plane spacing of the crystal, along with the range of temporal frequencies that need to be searched. Finally, the Q and sensitivity of the detectors will determine the allowable speed of frequency sweep in Hz per second. What we have is the product of 4 independent variables, where we are looking for particular combinations. It is possible that there will be detectable effects for a large number of different combinations of the 4 variables. In any case, it might make sense to conduct searches in parallel. It may be possible to make arrays of crystals, similar to integrated circuits, that test multiple angles at a time. It is conceivable that one VLSI chip might contain thousands or millions of test sites. It is conceivable that the search might require thousands or millions of such devices all operating in parallel.
11. We have presented the most pessimistic of possibilities. If Finite Nature is true, the experimental proof might be a lot simpler. Nothing has forced us to notice the

effects of the lattice because there is no acceptable experimental evidence. Three hundred years ago Newton could not have developed the Theory of Relativity because there was no acceptable experimental evidence.

Four Laws of DM

Never in the history of the world has so much been done, so many times, by so many people, proving and reproving an important point which has escaped almost everyone's notice; the most fundamental processes of physics are *computation universal*. From the Digital Perspective we conclude that this law of physics should come first, before all the justly famous conservation laws.

Law I The fundamental process of Nature is Computation Universal.

A fantastic observation about our world was the recognition of the possibility of building digital computers which are *computation universal*. "*Universal*" means that any such computer can exactly emulate the behavior of any other computer, so long as the first computer has slightly more memory than the other computer. If the fundamental process of Nature was not *Computation Universal* then that would imply that, the laws of physics rule out the possibility of constructing Universal Computers.

Finite Nature implies that at the bottom, there can only be finite things in finite regions of space-time. The implication is that somehow, those finite things change with time so as to produce what we call "physics". The nature of our world and the finite nature assumption imply that there is orderliness to what happens at the bottom. Thus we are left with the necessity of there being finite regions of space time each having one of a finite number of states and the behavior of all this governed by something other than locally generated true randomness (which we consider non-finite). Luckily for us, there is a kind of science of such things. It is the science of Finite State Machines. It is part of Automata Theory. We know that physics is Reversible and Computation Universal, so it is reasonable to look at very simple RUCAs before looking at complicated ones. However, the simplest RUCAs happen to be too simple. For example, many are just 2 dimensional. A common sense approach is to adjust the space of the RUCA to match known characteristics of the space of physics. We have to be careful to leave undone certain things because we are exploring a very large space of possible RUCAs. This requires us to match the most important and fundamental aspects of microscopic physics first. As we pull one RUCA after another out of a hat, so to speak, we have to keep in mind the totality of all that is physics, as a kind of attractor or heuristic, so that we get closer and closer to the real thing

This is a definitive and unambiguous result; we can, within the laws of physics, build Universal Computers. It might not have been so. Of course, we could always have imagined the idea of the computational universality of microscopic physics, just as we can imagine concepts such as infinity, continuity, differentiability, whether or not such things are a part of physics.

The following 3 Laws assume the Finite Nature Hypothesis.

The greatest physics experiment so far has been the great Universal Computer Experiment. The question that needed to be settled was the following "Is the most microscopic, fundamental process of physics computation universal?"

A fantastic observation about our world has been the recognition of the possibility of building digital computers which are computation universal.

Law II The state of any real, discrete system must have a digital representation.

Digital information cannot exist without a means of digital representation. Therefore, regardless of appearances, every physical state that can be said to represent information must have, somewhere, a digital means of the representation of that information. It must always be possible, in principle, to translate whatever digital information represents system information into separate and distinct digital numbers (integers) to represent all physical quantities, such as momentum and charge.

Law III Change in state must involve a digital informational process.

The only way that something can change is for the digital representation to change. The only thing that can change the digital representation is a digital informational process. The digital representation must be accessible to the process that changes it but it need not be directly accessible to physical experiment. For example, when an electron absorbs a photon and is thereby accelerated, that means that there is a digital process where the digital information representing the momentum of the electron is processed along with the digital information representing the momentum of the photon so as to change the momentum information associated with the electron.

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Law IV There must be the equivalent of a common reference frame, that establishes absolute velocity and angular orientation and that is accessible to all microscopic digital informational processes.

Absolute position, a sort of intergalactic latitude and longitude, is most likely implicit as opposed to explicit. What this means is that the absolute position is implicit in the location of the bits that contain the representation of a particle's other properties. While in concept there could be a process that changes that implicit information into a set of 4 (t, x, y and z) absolute, exact coordinates, we doubt that there is the realistic possibility of any practical implementation of such a process. It would require both a definition of the exact origin of the coordinate system (perhaps the center of mass of the Universe) along with a means of determining exact x, y and z distances to the center.

DM shows us that it is not possible for a digital informational process to allow for such fundamental aspects of physics as rectilinear motion or conservation of momentum without the equivalent of a fixed reference frame. In DM, angular momentum and linear momentum are conserved at the most basic and microscopic level. The consequence is that at macroscopic levels the ordinary laws of physics are independent of the linear motion or of the angular orientation of any chosen coordinate reference frame. We take Noether's Theorem (with a few adjustments) and turn her theorem on its head.

A Corollary of the first three Laws is that for any digital process, there are as many exact models as we might like; the only differences being matters of esthetics and economy. We assume that computer models of discrete physics will be discovered that are exact; with no approximations whatsoever. Of course, any such models that we run on real computers will suffer the limitations imposed by the amount of memory and the processing speed of the host computer. The memory will pose a limitation on the space volume, and the processing speed per unit of space volume will impose a limitation on the real time rate of the model. The space-time volume that can be modeled depends on the capacity of the computer system.

DM and the Facts of Physics

We can all agree with Newton's Laws. We can all agree with mathematical theories of relativity. We can all agree with mathematical theories of QED. We cannot all agree on the Finite Nature hypothesis at this time. Because DM is a model of physics based on *Finite Nature*, we do not know whether, ultimately, the correct model of microscopic physics will turn out to be absolutely and totally discrete (the *Finite Nature* assumption). It is interesting to note that there can be excellent computer models of continuous systems and, as we have suggested, there can be perfect computer models of all discrete systems.

In this book, we come to many conclusions about properties of our world that are a consequence of making the *Finite Nature* assumption. We must stress a most important conclusion: Whatever is true as a consequence of *Finite Nature* is still true, independent of the scale where space and time become discrete. Even if it's down at Planck's Length and Planck's Time, the assumption of finite nature imposes the same conclusions that would be true if discreteness occurred in the range of a fermi.

DM can be in total agreement or in close approximate agreement with all valid mathematical models of physics. However, DM is clearly in conflict with many of the philosophical conclusions thought to be consequences of mathematical models. DM introduces a new viewpoint that addresses certain shortcomings in our current picture of our world. The digital perspective shows how modern engineering can solve problems that have commonly been thought to be unsolvable in physics.

Science is unfortunately the victim of occasional explanatory examples of the following ilk: "Let us try to measure X by method Z, which seems quite general. It is elementary that we cannot measure X by method Z or any other method we can think of. Therefore, the conclusion is that there is no way to measure X. Furthermore, since we cannot measure X by any method we can think of, there is no reason to speak of X." Thus, spake Poincaré; and Einstein didn't complain. The only trouble is that neither could imagine what we know about today's technologies. For example, today we can easily define an absolute time reference and can build clocks that accurately keep absolute time.

We start with a definition of "*facts of physics"*. By that phrase we mean to include the generally agreed upon and accepted results from physical experiments. This includes actual experimental data and includes the mathematical models that fit the experimental data. It includes nothing else! The *facts of physics* shall specifically exclude all the conclusions that have accumulated over the years, that cannot be deduced directly from either what we have measured or from the accurate mathematical models of what we have measured. In doing so we must part with suppositions of such familiarity as to have all the power of persuasion that ought to adhere only to the *facts of physics*. Further, we must note that almost all natural language explanations of the *facts of physics* and of the consequences of the facts are also excluded unless they are able to be rigorously derived from just the *facts of physics.*

We ask just one indulgence of the reader. When you read some statement that seems just plain wrong, contrary to what you were taught and the opposite of what almost all scientists believe, ask one question before you get outraged or before you just give up:

"Is the statement actually in conflict with either the data acquired from any experiment or in conflict with accurate mathematical models of any such data?"

To drive that point home, we will start with two examples: the first simple and easy to understand, the second a very profound and confounding.

Now, I am very embarrassed to confess to you what I intend to do with the *facts of physics.* First, I will be trying my best to discredit some generally accepted ideas. It's not the ideas expressed in mathematical formulae but rather some of the conclusions as to what those formulae mean. Scientists try to enlarge our knowledge of the world by continuing past the rigorous process of getting experimental data and discovering the associated mathematical laws. They sail into uncharted waters by translating mathematical laws into natural language pronouncements. We cannot fault that process. It is an often necessary part of converting data and mathematics into knowledge. But it is possible for new concepts to radically change our natural language interpretation of old facts and formulae. We know that physicists who talk and write about physics might err with regards to their translation of experimental results into easier to understand concepts that tread beyond the strict interpretation of mathematical formulae. What is true is that they have no choice. What lets us gain new understanding is new knowledge. We must try to translate arcane experimental results into things we can talk about. We have to build conceptual edifices and connect them into the metropolis of modern science.

Normally we need new experimental data to overturn a picture of the world that got developed on the basis of much data and mathematical insights. The pictures we have of the world, in our minds, are not only a direct consequence of the data but contain extensions beyond the data. What we also know is that other pictures may fit the data and the math equally well and may end up making more or less sense in light of what other things we learn later on. Finally, we always hope for new experiments that might settle the new conceptual questions as they come up.

Our great experiment, proving that physics is Computation Universal, produced a tremendous amount of data. We have only recently begun to understand some of the other underlying laws hinted at in all this experimental data. It seems that this new understanding may profoundly change our views of the nature of reality, of the laws of physics, of the way things work. In particular, 3 key concepts have become clarified: *digital state, digital informational process* and *computational universality*.

The philosophical importance to physics of this new viewpoint may come to rival the philosophical importance to physics of conventional mathematics. It is amazing and fortuitous that properties of physics are so beautifully described by mathematical formulae. However, what mathematics can do is limited to allowing us to create high level approximate models that encapsulate our knowledge of physical processes. We can often solve such high level mathematical models so that we can calculate a future state, given an assumed or measured current state. A good example is the 2 body problem of the orbit of a single planet around a distant star. For such problems we can derive mathematical formulae that are parametric in time. This means that the work to calculate a future state is approximately the same, independent of how far into the future we are calculating. This is a property that is essentially always absent from any non-trivial digital, spatial, informational process. An example could be a set of Partial Differential Equations programmed on a computer and used to model hydrodynamics (Computational Fluid Dynamics). In all such non-trivial cases the work to calculate the future is almost always proportional to the total space-time volume. (Almost everything done on a computer falls into the non-trivial case. In the case of CFD the possibility of particles interacting realistically insures non-trivial behavior.)

The BLT Theory of Units

(The Bit, Length and Time; Not Bacon, Lettuce and Tomato)

Law I Bits are conserved (a +B, (1), or a –B, (0), cannot be created or destroyed)

Law II Space-time has 2-Parity (Black and White 4-D Checkerboard)

Law III Time has 6-phases East (x), Down (-y), South (z), West (-x), Up (y), North (-z); which gives a handedness to space; space is chiral.

Law IV The sign of charge is the total bit-space-time parity of a temporal transition.

Law V Reversing time reverses the handedness and the signs of all charges.

Law VI Individual Quarks and Gluons do not have complete momentum information

Law VII Every isolated complete particle must have a complete set of momentum information. (All isolated particles are colorless.)

One model of Physics is a 2 state, reversible, universal cellular automata (RUCA).

The nature of a RUCA is such that the state of any point in space is a function of the entire past light cone, (and of the entire future light cone). One often speaks as follows(in describing a Gedanken experiment): "…say we cause an event to occur at point P…". Such a statement must be inaccurate in a RUCA because everything in the entire light cone is responsible for what happens, and it is not possible to alter that. This kind of determinism also has the property of being unknowable in detail. From within the system, one can never tell exactly what is going to happen in advance, but can only calculate the probabilities for various events. The fact that events are deterministically related to both the past light cone and the future light cone is characteristic of such spaces. A locally determined microscopic state, decided by the experimenter, is just not a possibility.

We imagine that ones are conserved. Conservation of angular momentum is an obvious and direct consequence. In some sense the conservation of angular momentum is the most basic of conservation laws.

Conservation of Energy and Conservation of momentum are natural consequences of the basic rule (of the RUCA) and the fact that ones are conserved.

B is the unit of digital information. It is a bit of information. In particular, it is the information represented by a bit in a cell (a one or a zero for 2 state logic). A unit of spin (or 1/2 spin) is related to the smallest space-time orbits of a one bit. There is no most microscopic spin other than translational (orbital) in nature. In some sense, B has dimensions L^3T. This is the space-time volume of one cell. This observation is important in understanding gravity. Planck's Constant (∇) is 1B.

L is the unit of Length. The distance from one cell to the next is 1L. There are coordinate axes and 6 directions. East, Down, South, West, Up North. EDSWUN

T is the unit of Time. Time, like space, has a 2-phase parity. Space-time is a 4-D black and white checkerboard. The Duration of 1 time step is 1T

$B^{-1/2}L^{1/2}T^{1/2}$ is the Bit-Space-Time Parity. It is equal to +1 or -1

L^2 is the unit of Area.

L^3 is the unit of Volume.

L^3T is the unit of space-time volume.

V is velocity. V has dimensions LT^{-1}, which is the natural unit of velocity. This unit is the highest possible microscopic velocity. The speed of one cell per unit of time is
1 LT^{-1}.

A is acceleration. A has dimensions LT^{-2} , which is the natural unit of acceleration. It is the highest possible microscopic acceleration.

E is the unit of energy. The energy of a particle is proportional to the temporal frequency of a wave packet. The total energy represented by the wave packet is the sum of the energies of the parts of the wave packet. There is an atom (unit) of energy, and that is a pair of cells with the same spatial coordinates that changes state over one unit of Time. $E=BT^{-1}$. In one unit of time, one cell has changed state. Energy is the first difference of Bit with respect to time. Since 1's (and 0's) are conserved, Energy is conserved but microscopically, local transient conditions can temporarily violate conservation of energy. At every instant in time, each atom of energy has charge. Each atom of energy radiates wave phenomena. An isolated amount of energy generates an outgoing wave structure that propagates in all directions. The wave structure is made up of atoms that have space-time-bit parity. The wave front propagates at the speed of light. The bit transitions that make up the wave structure decrease in density with distance according to an inverse square law.

The Momentum of a particle is proportional to the spatial frequency of a wave packet. The momentum represented by the wave packet is simply the sum of the momenta of all of the parts of the wave packet. There are atoms of momentum, and they are pairs of adjacent cells, with the same temporal coordinates, that changes state over one unit of Length. There are 6 different atoms of momentum corresponding to the six ordinal directions. For each of the three coordinate axes, the direction of the momentum is + or - as determined by the combined space-time parity of the spatial state change. Momentum is BL^{-1} which is the smallest microscopic value of momentum. As with Energy, local transient conditions can temporarily violate conservation of Momentum.

Force is $BL^{-1}T^{-1}$. The atom of force consists of a cell transition, similar to momentum and energy, but offset in both space and time. Force is Momentum/Time. Force is the encoding of the information that changes momentum. What this means is that an atom of force can interact with an atom of momentum. The result is an atom of Energy. An atom of Energy can interact with an atom of Force to become an atom of Momentum.

~~13.~~Atoms of Energy, Momentum and Force interact in the following way: Force and Energy Momentum and Energy. Of course, a given 1-bit could be a component of Energy, Momentum and Force at the same time.

Angular Momentum and Action are both B, of course. The fact that we observe angular isotropy is a consequence of the absolute conservation of angular momentum because of the basic rule (ones are conserved and ones have angular momentum). Since conservation of angular momentum is exact, we see asymptotic angular isotropy as we measure and average above the scale of the cellular space. We believe that a most likely model involves a rule that steps through 3 symmetry states related to the 3 coordinate axes, simultaneous with 2 time phases related to the second order time system. Thus a bit may be in an orbit that takes 6 steps in order to complete one (or 1/2) unit of spin.

W is Power. Energy per unit time. $W=BT^{-2}$. This is the second difference of Bit with respect to time.

Moment of inertia. BT

Torque BT^{-1}. This is Force times Length.

Pressure and Energy Density; $BL^{-3}T^{-1}$.

Action B

Viscosity is BL^{-3}. This is quite amazing; viscosity is density of ones in some volume. Like the unit of velocity, the unit of viscosity is the highest possible value.

~~21.~~Charge, $B^{1/2}L^{1/2}T^{-1/2}$ or BT^{-1} $(B^{-1/2}L^{1/2}T^{1/2})$ Energy times the bit-space-time parity. The product of the 3 square roots of the 3 units (B, L and T) is where the + and - comes from. A charge fundamental interaction creates a force proportional to the product of 2 charges divided by the square of the distance. $F=q_1q_2/r^{-2}$ in units: $BL^{-1}T^{-1}= (B^{1/2}L^{1/2}T^{-1/2})(B^{1/2}L^{1/2}T^{-1/2})/L^2$

~~22.~~Charge Squared, BLT^{-1}, is bit times velocity or energy times length. A kind of bit momentum.

Current $B^{1/2}L^{1/2}T^{-3/2}$ or BT^{-2} $(B^{-1/2}L^{1/2}T^{1/2})$ Power times the bit-space-time parity.

Energy Density $BT^{-1}L^{-3}$.

Mass has the same units as energy, BT^{-1}, divided by C^2. Mass $=BTL^{-2}$. The model explains both the gravitational and inertial properties of mass and why they are exactly equal. Mass is made up of a number of units. Each unit has the same inertial and gravitational mass. The inertial mass is a consequence of the fact that an atom of force interacting with an atom of energy becomes an atom of momentum.

$G_{\mathbf{b}}$ is the Gravitational Constant. $G_b=k/G=BT^3L^{-5}$ $m_1A=Gm_1m_2/r^2$, $A=GML^{-2}$, $LT^{-2}=G\ BTL^{-2}\ L^{-2}$, $G=B^{-1}T^{-3}L^5$

If we use Energy for Mass: BT^{-1} instead of BTL^{-2}.

Acceleration equals Energy/Distance^2

$LT^{-2}= BL^{-2}T^{-1}\ (B^{-1}L^3\ T^{-1}) = BL^{-2}T^{-1}\ (BL^{-3}T)^{-1}$

The Units

There are just 3 fundamental Dimensions: Length, Time and the Bit. We will redefine other physical dimensions in terms of the fundamental units. In our conventional unit systems of physical dimensions, the Bit would have the same approximate dimensions as Planck's Constant Reduced, ∇. 1.054573 $x10^{-34}$ Joule second (kilogram $meter^2$/second). The reason that we say "approximate" is because it is likely that the actual most microscopic unit is smaller than Planck's Constant by some small factor such as 1/6. This is a situation similar to the way the atom of charge has been reduced to 1/3 of the electron charge.

The Design of a Particle

The object is to take the concepts of DM along with the known properties of particles -- particularly the informational properties -- and to come up with a plausible design. There is no chance that the designs given here are correct. We will be leaping to too many conclusions. We know of errors and inconsistencies. The readers will find many more. Nevertheless, we see no other way to proceed with the process of trying to explain what is clearly an alien conception. The point is that given some whole picture, we should be better able to grasp the significance of the DM approach. We believe that if DM is a good model, then the problems, errors and inconsistencies will all diminish with time.

As we learned about the atom, our models went from positive pudding with electrons for raisins to a little solar system with the nucleus as the sun and electrons as the planets. At that point, a few lay people wondered whether very tiny people lived on those electron planets. Both models had flaws and were essentially wrong, but nevertheless useful steps.

We start with something that we can know and that is that DM demands that the informational requirements exclude the concept of a simple point particle, a particle that is a perfect sphere or a particle that is as pure as just a charge, a rest mass and spin state. The reason is that somewhere, somehow, associated with the particle, there exists a substantial amount of information. Furthermore, DM insists that that information must have a digital means of its representation. In addition, the greater environment of the particle cannot be simple, in that it is clear that it also contains information that must interact with the particle. What is required is to find the kinds of structures that can, at the same time, embody the simple facts (type, charge, spin) along with the more complex facts (rest mass, energy, momentum). Somewhere there is a fuzzy boundary and inside the boundary is the particle and outside the boundary is the particle's environment. Because of superposition, some of the particle is beyond the boundary, and the environment intrudes into the space of the particle. We can choose, by definition, where to put that boundary. For atoms, we might have decided that the nucleus is the pure atom and that the messy and more complicated electron clouds are something else; the chemical atom. We think that present day concepts of the atom are fine, but with particles and their translational energy and momentum, we may have more of a choice. We will adopt the convention that a particle contains the digital representation of its momentum and energy (including rest mass). The extended informational wave structures associated with a particle will be called part of the particle's environment. For example, consider a photon. It has a precise energy and a precise momentum. However, when a photon passes through a narrow slit or through a tiny hole, it retains its energy information but loses some of its momentum information. Because of the relationship between energy and momentum in a photon, the only aspect of momentum information that can be lost is the directional part of the momentum vector as opposed to the magnitude of the vector. This is because in a photon, the energy and momentum are related by a simple formula, I.e. the photon changes direction but does not change frequency (or color). This means one of two possibilities are likely: The momentum information is separated into a rest mass and energy magnitude, then combined with a unit vector that indicates direction. If the momentum is directly represented as a vector, then particle interactions would need to do the arithmetic so that after the event the total momentum and energy are conserved. Of course, momentum is separately conserved along each of the three coordinate axes. All this leads to a likely class of designs.

QCD makes it clear that a particle such as a nucleon can externally manifest charge and spin in a simple and straightforward way, while hiding the greater complexity of the interactions of 3 quarks and various gluons. Of course, even an atom can do the same. This is a major conceptual problem: the combination of great internal complexity along with simple external characteristics. It is also clear that information is divided between what we will call the "nucleus" and the "environment". A single neutral Uranium 238 atom has 92 protons, 92 electrons and 146 neutrons. That means is made up from 806 separate charged particle (quarks and electrons). Every one of the 806 separate particles is a fermion, each with spin 1/2. However a U-238 atom can easily play the role of a simple, neutral, spin zero particle. It is clearly a boson (integer spin) particle. Much larger entities (such as a Millikan oil drop) can be perfectly electrically neutral while made up of a very large number of charged particles. The point is that in the digital world, it is not surprising that a great number of seemingly independent things can add up to exactly zero.

We know a large number of facts strictly from an informational point of view. For example, when 2 particles interact, they can each have their energies and momenta changed but the total energy and momentum are both conserved exactly. This is only possible if there is a sharing of energy and momentum information by some process that conserves both. The DM model addresses the issue of the conservation by assuming that the most microscopic representation of the energy and momentum information is conserved as a consequence of the basic DM process. This leaves the problem of the sharing and dividing of the information. We already understand this process with regard to spin and charge. We are not proposing something all that strange. We are merely saying that just as spin and charge are discrete, atomic and digital, so are momentum and energy.

We also know that some kind of momentum information is spread out in space around the particle, in the environment. This environmental information is different, in that it does not contain any momentum, most likely only information related to the direction of the particle's motion! There must be a steady interaction between the particle and the environment. The particle creates the environment information and defines certain of its parameters. The environmental information controls the particle in determining which way it will go. This process is easier to understand in the context of Reversible Universal Cellular Automata. There cannot be any conservation law about the environmental information, from the particle's perspective, since a particle can be repeatedly deprived of it followed by regeneration of new environmental information. A further argument as to why the momentum information cannot be only in the extended wave has to do with the results of an interaction. We cannot imagine any process that can perfectly gather up every bit of all the widely dispersed wave so as to exactly redistribute 100% of it to the particles that fly away from the site of the interaction. All of these things point towards the existence of a compact representation of the type of particle, the charge, the spin, the energy and momentum. The extended wave structure can also have momentum information but it seems highly unlikely that it has the only momentum information.

We propose that the nucleus contains energy exactly proportional to the number of energy atoms in the nucleus. We propose that the momentum is equal to vector sum of momentum atoms in the nucleus. We propose that within the nucleus are oscillations in space and time so as to drive the production of a wave structure with a temporal wavelength inversely proportional to the number of energy atoms and a spatial wavelength inversely proportional to the momentum magnitude.

What we are describing about energy and momentum means we must assume that there is a fixed reference frame accessible to the process that motivates the particles. In that frame, the bits that represent momentum and energy are obviously related to each other by the rest mass (which is zero for photons). Since the laws of physics are valid in any inertial reference frame, they clearly can be valid in a preferred reference frame. What we assume is that the processes of particle interactions effectively enforces the validity of the Lorentz Equations to govern the relationships between energy and momentum in different reference frames so that the observed spatial relativity manifests itself properly. While this kind of explanation may not seem as neat as Einstein's Relativity, it has the virtue of not involving magic and holds out the chance of being informationally possible.

This may sound like nonsense in the context of relativity, but we request your patience so that we can better deal with that issue in time.

The environmental wave structure is informational only and coupled to the nuclear wave structure. The information in the environment is, in some sense, the external embodiment of the arrow of direction. It steers and is steered. It leads and the nucleus follows. It is driven by the nucleus and drives the nucleus. It can be very extended in space. We will use this picture to analyze QED on a microscopic scale. On the other hand, despite having momentum information, the environment has no momentum! All of the actual momentum is in the nucleus.

The environment cannot change the momentum of a particle. The momentum is defined by momentum atoms in the nucleus.

Let us examine two particles, the electron and the photon. We will then try to generate the picture of what happens during an interaction.

The electron is characterized by being a spin 1/2 particle (a fermion), with a charge of -1 and a rest mass of m_e. The photon is a spin 1 particle (a boson) with a charge of 0 and a rest mass of zero. The photon can also carry charge information despite its lack of charge. (This is the case when a photon is the interaction vector between 2 charged particles.)

First of all, it is clear that an electron cannot simply emit a photon or absorb a photon unless the spin of the electron is reversed. All interactions that leave the spin of an electron unchanged, must involve a 2 photon process. As an example, consider an electron in a magnetic field. It can be accelerated so as to move in a circular orbit, without any change in spin. This process can be thought of as the interaction of the electron with a large number of photons, but each interaction must involve 2 photons, one absorbed and one emitted. The way to get an electron to emit a photon is to accelerate it. The way to accelerate an electron is to get it to absorb a photon. This is all just common sense.

An electron in orbit around the nucleus of an atom can interact with a photon in a number of unusual ways. An electron can be absorbed, and then re-emitted in phase. This means that the momentum information of the photon is unchanged, but its progress is delayed as the electron completes an orbit. The emitted photon can make use of the momentum information still in the space around the atom, that is, in a sense, left over from the absorbed photon.

The Digital Perspective & DM

Information must have a digital means of its representation. DM does not allow for such a thing as Information that simply exists, with no means for its digital representation. Consider a system of 2 particles that are in motion relative to each other. One can say that the state of the system represents an amount of information. We can ask “How many different states might the system be in?” The informational content would then be the Log (base 2) of the number of states. But where is the information? In DM what must be true is that the information is digital, represented by the state of various bits, where one can imagine a process that could translate the state of the bits into numbers to represent the spatial and velocity coordinates of one particle in a coordinate system based on the other particle.

The observation that a particle moves must mean that digital information is being processed. That process changes the information as to where the particle is. How much it gets changed is controlled by the digital information that represents the velocity. Acceleration occurs when the information in a field (or the interaction with another particle’s momentum information) changes the information that represents a particle’s velocity. All processes in DM (angular momentum, momentum, energy, force, charge, etc.) have informational equivalents.

Certain laws of computation further limit what can happen in DM. For example, consider the possibility of an *oracle*. An *oracle* tells us the future state of some system. Of course, this works fine if what you ask of the *oracle* is the date and time of the next eclipse of the Sun. On the other hand, if you wish to be able, in general, to know the exact future state of any microscopic region of space, this is forbidden by the *speed-up theorem*. What the *speed-up theorem* implies is that there is no way in general, to know the future state of a computation other than by allowing it to go through all of the steps of the computation. In DM things are further complicated by the I*nformational Cone*.

The Informational Cone

This is both similar to the *light cone* but still drastically different. If one wants to consider the region of space in the past that might affect a particular local event, it is normally in the light-cone. This is a region of space-time that extending into the past and away from the event. It is that region of space-time from which a photon might have departed and arrived in the spatial and temporal vicinity of the event. In an ordinary UCA (non-reversible Universal Cellular Automata) there is a similar *Informational Cone*. If one wants to consider the region of cellular space in the past that might affect a particular local event, it is normally in the *informational cone*. This is a region of space-time extending into the past and away from the event. It is that region of cellular space-time from which the state of a cell might have affected the state of cells in the spatial and temporal vicinity of the event. So far, so good. What we see is an apparent similarity between the *light cone* of physics and the *informational cone* of the UCA.

A closer look at the details reveals a problem with the concept. If we would like to understand the consequences of making a change, we must consider the following. All irreversible systems have the property that there are states which have more than one predecessor state. In other words, the root cause of irreversibility is that for given states of the system, there are sometimes more than one possible predecessor state. It is the impossibility of determining which were the actual predecessor states that causes the system to be irreversible. But even irreversible systems, such as a discrete but irreversible model of physics (the typical computer model) are largely deterministic in the reverse direction. The extent of that determinism is usually underestimated because of the complexities involved. Given an attempt to trace the operation of an ordinary computer in the reverse direction, it is easy to see how various constraints impose what might be called “long range reversibility” on the process. For example we will consider the simple computation of A←A-B in an ordinary computer and then consider it in the reverse direction.

Forwards:

Fetch from register A (the minuend) in memory and put the contents into the accumulator overwriting the previous value that was in the accumulator.

Fetch from register B (the subtrahend) in memory and subtract the contents from the accumulator.

Move the results from the accumulator to A, overwriting the prior contents.

In reverse:

3. Fetch from register A in memory and put the contents in the accumulator.

2. Undo the subtract and store the subtrahend into B. There is a problem, since subtraction is irreversible unless one has, in addition to the difference, either the minuend or the subtrahend. However, when a reversible store operation is performed, the thing being stored must match the thing already in memory. Therefore, during the store to B, we find out what the subtrahend was! Knowing that, we can do the reversible generation of the minuend.

1. Take the minuend from the accumulator and store it into A. Restoring the accumulator is either impossible, or becomes possible as the process proceeds in reverse.

Assume "An Event Happens at X, Y, Z, T"

It is common in the world of physics to make such statements. It is a part of our philosophy and culture that we believe that we can imagine a system and imagine an initial state and ask "What happens next?" Of course, in a sense, there is no problem with the supposition. However, if DM is true, and the workings at the bottom in physics are those of a RUCA, then with regard to the most microscopic events, we must change our language and our beliefs.

Like mathematics, DM need not obey laws of Physics even if it models Physics!

Physics Like Properties – Based on B, L & T

The simplest part of the BL&T theory is time. But it's not too simple. We can assume that *the time* is an integer that started out at zero and has been counting up ever since. As far as the physics is concerned, we are only interested in time Mod 6. The CA rule that governs how things change has a spatial orientation. There are 6 different directions and they are cycled through one after another. More on this later.

The space is just like an ordinary table salt crystal; NaCl. All told, it is a cubic array of ions. In a cubic array each cell has 6 closest neighbors and there are 3 favored axes which form the x, y and z coordinates. However if one looks at just the Na ions, then they form a FCC (Face Centered Cubic) array as do the Cl ions. An FCC array is just like the packing of spheres; each cell has 12 closest neighbors. In addition, there are 6 favored axes. In DM space, we can think of the Na ion array as the Real Array and the Cl ion array as the Imaginary Array. We imagine that somewhere there is a Real array cell with spatial coordinates 0,0,0. Every set of three integers forms a good array address (up to some finite limit) while every array address is a set of three integers. The sum of the three spatial coordinate of every cell in the Real array is even and the sum of the three spatial coordinates of the Imaginary array is odd.

The Array as defined immediately confers some physics like attributes and seems at odds with others. First of all, as in physics, the laws are independent of where in the space one is. Locally the 3-D Cartesian nature of the cellular space is similar (especially with regard to connectivity) to the space of physics. Finally, DM time has an opportunity to play a role in explaining the chiral nature of time reversal with CPT parity in physics.

The letter "**B**" is our symbol for the Bit in the theory of DM. It is a cell in a 3-D, Cartesian lattice that can be in one of 2 states. Instead of the usual "1" and "0" of ordinary digital logic, we prefer to use "+**B** " and "-**B**". The only way in which the state of a cell can change is for some neighboring cells to exchange change states. A swap or some other permuting law must be the most basic action since space is filled with every cell being a +B or –B in the Real array, and a +iB or –iB in the Imaginary array. Further, all B's are conserved. They can not be created or destroyed.

So, a swap is when 2 neighboring **B**'s exchange places with each other. We will use the word "swap" to mean some kind of permutation over the cells in a small, well defined neighborhood. We will try to explain the efficiency and purpose of all the various assumptions that go into the DM theory, including the unusual structure of space-time, but will do so later. In a sense, the DM lattice can be thought of as 2 lattices, a Real lattice and an Imaginary lattice (in the mathematical sense). The Bit is the binary digit (**B**); one Bit; We list below, various characteristics of **B**.

B is the informational thing that has state.

B is an atom of state or information.

If you think of a cell as a box, there are no empty cells, every cell has some kind of **B** in it.

B's physical dimensions are the same as ∇'s.

While **B** is 2 state, the 2 states in the Real Lattice are **+B** and **–B**.

The 2 states in the Imaginary Lattice are **+iB** and **–iB**.

Thus, all **B**'s can be defined as follows: $\mathbf{B}=\sqrt[4]{1}\ \nabla/u$

u=small number, e.g. 6
$\sqrt[4]{1}=\{1, -1, i, -i\}$
$\nabla=1.05457266\text{x}10^{-34}$ Joule Second (M^2KS)

In the DM system **B** is a unit as are **L** & **T**.

B, L & **T** are the only units in DM.

In DM half the **B's** are either +**B** or –**B**,

The other half are either **+iB** or **-iB**.

The assumption that half the **B**'s are +**B** or +**iB** while the other half are **–B** or **–iB** is more interesting. It might be true and it might not be true.

Each and every B is absolutely conserved. A **B** cannot be created or destroyed. It cannot change into a different kind of **B.** The only things that can happen is that a Real **B** can swap places with a neighboring Real **B** when the time is even, or an Imaginary B can swap places with a neighboring Imaginary B . If they both have the same sign, then it is the same as though nothing happened. However, if they have the opposite sign, then something has happened! And it's the only thing that can happen; two neighboring **B**s with opposite signs swapped places! It sounds too simple and maybe it is. There is more to it however. During a single time step (when the time is even) the thing that determines whether or not 2 neighboring Real **B**s swap has to do with **B**'s in the neighboring Imaginary neighborhood. During the odd time steps the Real array determines what gets swapped in the Imaginary array.

Remember, in DM all fundamental constants of the Theory are small integers.

Simplicity Itself

Our goal is to start out with something very simple, but following Einstein's Rule, "…as simple as possible, but not too simple!" Every attribution of a property to the DM model is there in order to allow a closer match to properties of physics. Our situation is like the theory of Quarks before there was color. It was good at explaining some things, but left serious problems in the theory. Early DM is far ahead of early quark physics in that DM has many more serious problems than Quark theory ever had! Nevertheless, what is interesting is the following: when one understands DM, a fairly easy task, one should reflect on how many aspects of physics are modeled by this infant theory, with its very few assumptions, as opposed to pointing out all the things it is incorrect about. What good is an infant? Not much unless it is nurtured and allowed to grow into an adult.

In DM, the only somewhat complex structure is the space-time lattice. All of the rest of physics is a consequence of the algorithm that governs the space-time lattice and the initial conditions: the state of the space-time lattice. In other words, instead of defining a simple space and putting in all the rest of physics as ad hoc additions, we start out with a slightly more complicated space and recover more physics than we put in. DM is a discrete field theory where the complete set of particles seen in physics, along with all the laws of physics will, hopefully, all be consequences of the field. This is very different from most other field theories. Of course, whatever we do has to be Universal, but Universality is no longer a difficult task. When we were struggling to find any simple universal CA in the 1970's, Feynman playfully annoyed us by suggesting that probably almost all non-trivial CA's were universal. Well, now we know that it's a tautology to say that all interesting CA's are universal. "Interesting" is a good definition of "non-trivial". And now it's so easy to find universal CA's that whether or not Feynman's statement was right his point was correct. As a result, we no longer have to concentrate on the universality aspect; first we get other things right and then we make whatever minor changes are necessary to include universality as one of the properties.

What is the Correct DM Model?

If the DM theory is correct, we will be able to find as many exact DM models of physics as we might like. For every proposed DM model that is Universal, including all the models in this paper, There is an initial condition that results in that model being an exact model of physics. This is good and bad when looking for a good model of physics. The solution is to realize that proper criteria for good modes must take into account the overall complexity of both the definition of the model and the definition of the initial conditions. The best models are those that portray physics accurately with the smallest number of assumptions.

We have proposed 2 prospects for the structure of space-time. Of course, the possibilities are not limited to these two structures. One we call "4DST" for 4 Dimensional Space Time, the other is called "Salt" since it resembles a crystal of ordinary table salt NaCl, Sodium Chloride. Both of these structures share some common characteristics: only 2 time states are explicate during a time step, and time is multi-phased, where each phase of time is associated with a spatial direction. There are various considerations that support both structures, and for that matter, many other structures. Rather than consider in great detail all the reasons why one structure is better than another, we wish to proceed with generating the whole picture, more or less consistent with one of these 2 structures.

As an example, we have a reasonable model for Mass, which is that it is, in essence, frustrated momentum. In DM, a particle's total momentum is represented by a large number of momentum atoms. In the case of a photon, it has momentum, but it has zero rest mass. One of our models for rest mass, involves particles where there are a number of momentum atoms, whose total momentum adds up to zero. This is the rest mass of the particle. What that means is that, in the case of a photon, it must be possible to have a particle with any value of momentum, while the rest mass is zero. In the Salt model, it is hard to see how this can be possible, since with regard to momentum atoms, for each possible direction of a momentum atom there is just one momentum direction that is perpendicular to it. There is now way to have 3 sets of momentum atoms where each member of one set is perpendicular to all the members in the other 2 sets. The result is that there must be some momentum that contributes to rest mass. Thus, all we can say is that there are 2 assumptions that are mutually incompatable: 1. Rest mass is frustrated momentum, 2. The structure of space fits the Salt model.

We often discuss energy atoms and momentum atoms. Again, these are not the only possibilities. For example, energy might be in the form of the frequency per bit. This is a concept more at home with a field theory approach. If empty space in general has an average frequency per bit, then a region with greater energy (a field or a particle) would be a region with a higher than average frequency per bit. The number of possible conceptual forms in which energy, momentum, rest mass, charge and spin can be represented is very large. Each such concept can be tested against various principles, can be looked at for mutual consistency, etc. so as to move towards a more realistic set of assumptions. In DM, some of that process has already taken place, but it is obvious that much more of that kind of process is needed.

The Fundamental Properties of Physics

We are going to list what we considered as the fundamental properties of physics that we are trying to capture in the DM theory. It is a somewhat surprising list. The list is in the order that was kept paramount as a guide the development of DM.

Computation Universality

Reversibility

Local 3-D connectivity of space

Chiral Space-Time structure

CPT parity for Time Reversal

Conservative Laws

Angular Momentum

Linear Momentum

Energy

Charge

Color Charge

Mapping of properties of physics to properties of RUCA

Why B, the Bit, Is What It Is

We have a simple yet complete definition of the **B**. However the **B** fulfills a number of requirements. First and foremost, it is the element of state. Every point in space-time has a **B** in it. But space-time is divided into 2 regions; Real and Imaginary. In space-time we can think of every point as having 4 integer coordinates; x, y, z and t. In the case of Real space-time, the sum of the 3 spatial coordinates is an even number. In the case of Imaginary space-time, the sum of the 3 spatial coordinates is an odd number. This is done in order to facilitate the mathematical derivation, from the definition of DM, of certain equations of Quantum Mechanics. In Real space-time we have **+B** and **-B** while in Imaginary space-time we have **+iB** and **–iB**. The set of 4 **B**s can be thought of as $\mathbf{B}^{1/4}$. This kind of apparent complexity is not necessary if one only wants to think at the level of Automata Theory, where each and every **B** could be just **True** or **False** and where the structure of the RUCA could be 2 dimensional or even an ordinary Turing Machine. However, our goal is to make the connection between the Digital Informational Process and physics as close as possible, at every turn. This is the wonder of the Universal Machine. It's actually a handicap to be looking for a DM model of physics when you know that if any Universal Informational Process can exactly model physics, so can every such process. The answer is to understand that it's the totality of the concepts that go into the model, not just the Universal substrate. Nevertheless, the nature of the Universal Substrate affects the complexity of the subsequent rules. Good intuition, based on experience with RUCAs and physics, seems to be the key.

Why B has the Dimensions of Angular Momentum

In DM we have nothing to work with but space-time and the element of state. We want a complete theory where we can find ways to naturally express fundamental aspects of physics. We start with a Cartesian space-time lattice, which gives us two units, Space and Time. That fact and a little bit of dimensional analysis leaves us with a large number of possible choices for the **B**. If we express the **B** in SI units, we know that it must include Mass as one of the units. Then why not have the **B** be the unit of Mass? The answer is a little complex. The nature of the RUCA rule is such that the motion of **B** is restricted to a conditional swap between neighbors. Further, the swap is a step in one of a small number of different orbits. This approach is not arbitrary. It is the source of space-time chirality. We can assume for now that the orbit takes 6 steps. It's the nature of the **B** to be in an orbit. The orbit can change but it is still always an orbit. This led quite naturally to the idea that the **B** should have dimensions of angular momentum. In SI units that is ML^2T^{-1}. There are a number of other reasons. There is no natural unit of mass but there is a natural unit of angular momentum, ∇. Finally, using the **B** as the unit of angular momentum, the derivation of the DM units for other physical quantities, such as energy, momentum, force, charge etc. was so serendipitous and logical as to bring to mind what must have been the experience of Mendeleyev when he first made up the table of the elements. This will all become perfectly clear when as we describe the DM models of other physical units (beyond space, time and angular momentum).

What is

All spin is orbital.

Universality implies no need for more states.

Finite information and finite computation in any finite volume of space-time.

Each bit is functionally related to ≈1/2 of all bits in the Information Cone.

What is DM Space-Time?

We have learned many principals that seem to make sense for the DM model. In general we have found a great convergence towards certain kinds of structures and processes. However, everything defined here is speculative, as to the actual efficacy of the model. Nevertheless we continue with the policy of describing definite models as examples of what might be the most appropriate model. It is important to keep in mind that if Physics can be well modeled by any RUCA, it can be modeled by every RUCA. However, we know that some RUCAs will be much more economical and esthetically pleasing than others.

What we think of as *space* is a combination of 2 things. There is the RUCA; an array of cells, and there are the states of the cells. At any point in time, every cell is in a definite state. The RUCA rule is what defines how the states evolve with time. The rule is a simple set of statements the are all of the same form: A given configuration of cells and their states is assigned a transformation that may change the configuration of states for that neighborhood of cells. The rules have to cover all the possible configurations that might arise, with an answer as to what should happen in each and every case. Normally, the rule doesn't have to be explicit about each state; for example, one set of rules has the property that nothing changes. This may be the case for a great many different configurations of states. It is usually true that there are easy ways to describe the whole set of such states without having to list them all.

What must be true of the space, the states and the RUCA rule, is that all of the most microscopic properties of physics are simple consequences. This means that matter and energy, charge, momentum, spin, etc. must all be emergent properties of the DM model. We can start by considering the properties of *empty space*.

Empty space has many definite properties. First of all, what we mean by empty space is space with no matter in it. There are many other inhabitants of so called "empty space". For example, there are things that produce waves in so called "empty space".

DM space-time is a RUCA that is the home of the meaningful digital information that represents the particles and fields that are the basic ingredients of Physics. All particles and all their properties are emergent quantities of the Digital Field Theory

The structure of the RUCA is a 2^{nd} order Cartesian space-time lattice. Every cell has 3 integer spatial coordinates and one integer time coordinate.

While the totality of the entire finite space of the modeled universe is explicitly present, only 2 adjacent time states are present. This allows for a second order system that gives an easy representation of many physics like characteristics. However it is not the only way to accomplish the same task. For example there are variations of the Margolus rule, wherein time has 2 phases and every cell is in one of two different neighborhoods depending on the phase of the time. In DM, we choose to go with the 2^{nd} order rule for a number of reasons.

In the SALT model of space-time, the sum of the 3 spatial coordinates of a cell is the spatial parity of the cell. If the spatial parity mod 2 is 0, $P_2=0$, then the cell is in the Real array and the time coordinate is also 0 mod 2. If the spatial parity mod 2 is 1, $P_2=1$, then the cell is in the Imaginary array and the time coordinate is also 1 mod 2. Thus the space-time parity of every cell is always even; the space-time parity of all cells, $P_2=0$ This means that every Real cell has 6 Imaginary neighbors and every Imaginary cell has 6 Real neighbors. However, the Real array is a Face Centered Cubic array, where each Real cell has 12 Real nearest neighbors, and the same for the Imaginary array.

The structure of the SALT RUCA is essentially the same as that of an ordinary salt crystal, NaCl. One can think of the Sodium ions as the cells in the Real array and the Chloride ions as the cells in the Imaginary array.

When the time

The sum modulo 6 of the time is part of the state information that goes into the RUCA rule.

The Black Hole in DM

The Future and Absolute Space Time

The fact that we can build AT-Clocks implies that the local determination of some kinds of standard spatial and temporal reference systems is possible. Now that that door has opened, we may ask "Is it possible that we might discover and measure motion through and orientation in absolute space-time?" Our answer is very simple: "There are no mathematical laws of physics that imply the impossibility of such things!" Instead, what we have is *Laws of Physics* written in English or German or other natural languages, which state the impossibility of such things. Most people believe that such *Laws of Physics* are true statements about what the mathematical laws imply. The problem is that there is no rigorous method of correctly producing natural language *Laws of Physics*. Unfortunately, some so-called *Laws of Physics* are not accurate reflections of the consequences of the mathematical models.

It seems to be the nature of certain scientific personalities to search for and welcome the opportunity to invent laws about what cannot be done or to want to believe in such laws that others invent. History, both ancient and modern, is replete with examples. Sometimes the nays Sayers are correct. We can prove, via the Theory of Equations, the impossibility of both squaring the circle and duplicating the cube using the methods of Geometry.

With the advent of Newtonian Mechanics we were faced with a new mystery. The law of universal gravity replaced other ad hoc explanations for parts of physics ranging from the laws of falling bodies, the motion of the moon and planets and the ocean tides on Earth. But what was the explanation of gravity? Newton's famous statement on the subject was "I make no hypotheses." That wasn't very satisfying, but the law of gravity lets us calculate the motion of the planets whether or not we happen to understand how it works. On the other hand, there has never been a culture surrounding the theory of gravity that claims that we cannot know how gravity works or that there is anything about gravity that we can never know.

The whole philosophy of "what we cannot know," greatly expanded with the development of both Relativity and Quantum Mechanics. It is certainly true that

Quantum Mechanical experiments evoke questions whose answers are unattainable or otherwise limited. Einstein mentioned gedanken experiments attempting to show that things formerly thought of as absolute were actually relative. To many, this seemed a philosophical revolution overthrowing the philosophies associated with Newton and Laplace. Like all such revolutions, this one carried to excess. DM is the opposite of QM in that it implies the possibility of a most exact understanding of the processes of microscopic physics. Dm is the opposite of Relativity in that it denies that we cannot determine the simultaneity or order of event, or absolute motion. What is certain is that Laplace's vision of taking the current state of the Universe and calculating a future state applies to DM in a limited way. DM allows (in principle) taking the present state and calculating the next state. Of course that process could be repeated, but the amount of computational work is, in general, proportional to the space-time volume. From a practical point of view, we don't have enough computational resources to compute anything other than the evolution of a very microscopic space-time volume. DM makes clear that that determination can never be made of a portion of real space-time as a prediction. It is an open question as to whether or not we can ever measure what was the exact state of some miniature space-time volume. It seems unlikely but then, who knows?

It may be possible, at some time in the future, to modify an AT-Clock, so that in addition to keeping local time and UITC, it keeps a close approximation to RUCA time. There is no possibility of its being able to keep time with the resolution of RUCA time, because the time resolution of any physical clock would be far too large. It would suffice for the AT-Clock keep RUCA time within a limited error band. It seems reasonable that some physical process will be discovered that allows an AT-Clock to synchronize with RUCA time. This would mean that no time error whatsoever would accumulate. In the same vein, synchronization with the RUCA substrate would allow for the exact determination of the AT-Clock's angular orientation with respect to the RUCA along with the AT-Clock's components of velocity with respect to the RUCA.

What is DM Time?

DM is a model of physics that exists in a RUCA. A RUCA is a Reversible Finite State Machine (RFSM) which is one of a number of different systems that is part of Automata Theory. In Automata Theory, one can find a rigorous definition of *time*. However the time of Automata Theory is not the time of physics. They are related but different.

In Automata Theory, we make great use of the concept of *state*. The idea is that, at a point in time, a system might be in one of a number of distinct states. Today, we might call those states, "digital states". The evolution of an RFSM can be traced by the series of states it passes through. While in some state, the next state is determined by two things: the rule that governs its behavior and its present state. In an RFSM, time is essentially like a sequence of integers; 0, 1, 2, 3…, modulo some base N. Since the machine is finite, after N steps it will find itself in the same state as at the beginning. A Reversible FSM has another rule that can allow the process to proceed backwards in time. When proceeding backwards, an RFSM exactly retraces its steps in reverse order. We can then think of time like the sequence of integers …7, 6, 5, 4… .

What we imagine is that a Finite State Machine makes a transition from one time state to the next, but that nothing is happening while it is in one time state. Unlike an analog clock, with a second hand moving continuously to mark the passage of time, the FSM is like a digital watch where the time stands still for 1 second, and then instantaneously jumps to the next second. Thus time is a variable, t, that is always an integer, where it can only proceed from its current value, t, to either t+1 (normal time) or to t-1 (reversed time). All we know is that a system in some state at t, is in a new state at t+1, as determined by the rule. There are variations on this theme, but all the variations are merely special cases of the more general Finite State Machine.

In DM, we make time and the passage of time more complicated than that just described. The purpose is to thereby make the overall system much less complicated. Nevertheless, from a theoretical point of view, the DM is simply a RFSM and could be accurately described as such. The result would be that the state information and rules would both be greatly expanded and made much more complex.

The Nature of Time in the DM RUCA

In our attempt to map the characteristics of the Digital world of RUCAs to the known facts of physics, we have arrived at a specialized form of RUCA. It is still a Reversible Universal Cellular Automata but it deals with time and space in a novel fashion.

In the RUCA as in any CA, we can think of time as an integer, t, which is counting. However, in the DM RUCA, t modulo k, where k is a small integer such as 6, is of great significance. There are many reasons for this conclusion. First of all, this concept of a more complex interpretation of time opens the door to extraordinarily simple models of many aspect of physics.

The Rules or the Initial Conditions

A wonderful aspect of all Universal Digital Systems is that we can almost arbitrarily partition the structure of the system between the rules (the geometry, connectivity and program) and the initial conditions (the actual state of the system when it goes into operation). We can always make the computer be the simplest of Turing Machines, or a very simple CA using the Banks Rule, and have a complicated set of initial conditions that gives the desired behavior. The other extreme would be to put all of the design and complexity into the rules (the program) and to have the initial conditions be as simple as possible. We believe that the greatest economy and the most esthetically pleasing solution is to divide this problem up so the most of the requirements are met by rules. This allows the particles to be emergent as opposed to being part of the initial conditions.

Two of the 7 constants of the DM theory have to do with the rules and the initial conditions. The rule is a simple program for the operation of the RUCA. There is no standardized language or convention for describing such rules, but in general, one tries to list descriptions of neighborhood state configurations along with what is supposed to happen in all the cases where something does happen. The result is that the “rules” for most simple UCA’s can be written in a few lines of text. In Conway’s game of life, each cell has 8 neighbors (a 3x3 neighborhood). The rule is as follows:

A cell with exactly 3 neighbors that are one becomes a one, with exactly 2 neighbors that are one, it stays the same; in all other cases it becomes a zero.

The above statement of the rule for Conway’s game of life took 43 words (156 characters). The Game of Life is a UCA. That means, if space and time are discrete, a large enough version of the Game of Life could exactly simulate the laws of physics and exactly simulate the entire evolution of the Universe, correctly in every microscopic detail! However, while we know that the mapping of physics (with its 3 dimensional space and reversibility) onto a 2 dimensional, irreversible Game of Life is possible, it is also horribly inefficient and esthetically obnoxious. Almost all of the computational power of the CA would be spent overcoming the fact that Conway’s Game of Life is 2 dimensional.

There are 3-D RUCAs that start out having features that are much closer to physics and our world. A rule that does physics in an acceptable fashion will not be much more complicated that the rule for the Game of Life. To be specific, instead of 43 words, it might need as much as 100 words. Of course, a natural language such as English is not the best way to express the rule for a Cellular Automata. The point is that however it is expressed, the rule will be simple and easy to understand! It might seem arrogant of us to boldly assert that the rule will be simple. We can do so because we now know that RUCAs have simple rules, regardless of consequent complexity, and there are no logical reasons why the rule needs to be complicated. In a way this is like knowing that the definition of the integers and of arithmetic is simple, regardless of the complexity of things that can be done with arithmetic.

The final constant of the DM theory is the constant that defines the initial conditions. For every single UCA, there is an initial condition that will cause it to do a computation where a subset of the cells in the UCA, at a subset of points in the UCA time, will exactly model the DM physics. One might ask, “If any UCA will do, why worry about which UCA is being used?” The answer is that the complexity of the initial conditions and the efficiency of the process will vary for all the different kinds of UCAs. But the extent of that variation is almost beyond imagining! Some UCAs might take twice as long to simulate a second, but more likely it will take 10^{1000} times as long. With regard to the initial conditions, things are simpler.

The specification of the initial conditions is given as a simple program that can put the initial conditions into the UCA. This means that the size or complexity of the initial condition specification is about the same for both an initial condition that starts out with nothing but a small group of bits which end up causing the Big Bang, or with the same sort of thing while wallpapering all of space with a simple pattern. In the tradeoff between initial conditions and rules, it is sometimes useful to further simplify the rule by starting space out as filled with a repetitive pattern; a sort of 3-D wallpaper. The complexity of the initial condition is the size of the program, not the number of bits that need to be set up in the UCA.

These two constants of the DM theory, the Rule and the Initial Condition, are both very simple and short computer programs. They are very different in that the Rule is the program that the RUCA follows, while the Initial Condition is a program for some ordinary computer that simply fills the space up with the proper set of bits so that it can start into operation properly. However these 2 constants are described, it is inconceivable that their description could possible take in excess of one paragraph of easy to understand information in order to produce a universe with the physics of our universe.

To be complete, we have to face a possibility similar to the thoughts of the creationists. We don't know whether or not the state of the Universe is the consequence of having been started back in the big bang, or started in some state where it began with a history that implies the big bang. While the latter supposition is grossly complicated as compared to the former, in DM both are possibilities. As we have done before, we could rely on Occam's Razor to assume that things started out in a simple state. In this case we have a far more powerful argument that virtually rules out the idea of the creationist viewpoint of DM.

What we know about computation allows us to assert that the only possible way to "start in the middle" with a complex universe, that has a history of a past that never occurred, is as follows: One must somewheres and somehow, on some UCA or equivalent system, start out a system at the beginning of the history (the Big Bang) and run it forward to the state where one wants to start another system out in the middle of the evolution. This is, from an informational viewpoint, exactly the same informational process as starting out the system at the simple beginning (the Big Bang). In one case things are started out on one computer then transferred to another, in the other case they are started out on one computer and continued. The informational processes are absolutely identical making it meaningless to worry about which is the case.

Why DM Time is Complicated

First of all, DM time is actually very simple, but not too simple. The time of ordinary physics is as simple as it can be. The time is a number that is always becoming larger, with no other distinguishing features other than its relation to various physical processes. A good question is "Why tamper with such simplicity?" The answer is that the continuous time and space of ordinary field theories requires that particles be added like raisins in a pudding. We want a field theory that may be a bit more complex in its most basic features, but which is all there is. We are trying to invent DM space-time so that all else in physics simply emerges. This is such a grand idea but it can't just happen unless the field theory has all the absolutely necessary machinery. What turns out to be fundamental in DM is often different from what one normally thinks of as fundamental in ordinary physics.

With regard to time, we consider the experimental evidence for CPT parity to be of very great significance. We believe that it cannot be a property of a few odd particles, but rather that it is an intrinsic property of space-time, which is, in general, hidden just as the quantization of space and time, the fixed reference system, angular anisotropy are all hidden characteristics. Further, just as there are experiments that clearly show the existence of CPT parity, there may be experiments that show all the other hidden characteristics of physics.

In the Real array, where the space parity is even, each cell has 12 nearest neighbors, all those whose

Why DM Space is Complicated

DM space is made complicated in the same way and for the same reasons that DM time is made complicated. Every cell in DM space-time has a set of 4 integer coordinates. The sum of the four coordinates taken modulo 2 is always 0. What is significant is the cell temporal parity modulo 6:

Thus cell parity separates the cells into 4 kinds different kinds. As mentioned earlier, those cells with odd parity are part of the Imaginary array, and those with even parity belong to the Real array. Further, those with Those with odd

The Big Bang in DM

It seems likely that a very simple initial condition could give rise to this universe. In the game of life, which is a much simpler 2D UCA, there is a simple configuration of 5 cells, called the R pentomino, which gives rise to a surprising amount of complexity. However, after a short time, the complexity fades away leaving a number of gliders flying away plus a bit of scattered fragments. There is no doubt that a slightly more complicated rule can give rise processes that are themselves Universal and capable of exhibiting continuous, arbitrarily complex behaviour.

What Was Before the Big Bang?

We imagine that the big bang is coincident with *The Time* being equal to zero. That is when time began for our Universe. Therefore, when we say "…before the big bang…" we are not referring to a temporal predecessor to the big bang in terms of the time of our Universe. Rather we are referring to something else. The problem is that it is only an assumption, but perhaps a good one, that in some other place (not in this Universe) that there is the same sort of time as there is in our Universe. In that case we will refer to events in that place we choose to call "*Other*".

In general, here is what we imagine. In Other, a RUCA was set up or constructed. The rule was built into the RUCA. Initial conditions were set up and the RUCA was put into operation. Within the RUCA, the rule and the initial conditions resulted in operation of an informational process. The laws of physics, the matter and energy in our Universe, and the beginning of the Big Bang are what went into the initial conditions of the RUCA.

So, the answer to the question is that before the big bang must be referring to time in another Universe. What happened was that the preliminary steps to setting up a RUCA to run our Universe proceeded until the system was ready to start with the Big Bang. Then it started and time in our Universe began.

This description of what happened eliminates one paradox. Given a physics that has conservation of mass-energy, we must face the fact that there is a lot of mass-energy present. Even if there are models that claim that the total mass-energy of the Universe may be equal to zero, that doesn't explain where the laws of physics came from, or what precipitated the Big Bang. There is no doubt that all explanations of what might have precipitated the Big Bang require some kind of magic in our Universe. DM does not. What DM requires is the existence of *Other*, where the rules (or Laws) are undoubtedly different.

What is *Other* Like?

First of all, there is no reason whatsoever to suppose that the laws in *Other* are like the laws of our world. This is an important concept, for it tells us that there is no reason to try to imagine that the RUCA is in a place where our laws of physics have any application. On the other hand, it seems that what little we understand about computation would still apply in *Other*. Given DM we might wonder, "What might we be able to know about *Other*?" Here are some questions and possible answers:

How many spatial dimensions does *Other* need?	Any number from 1 on up. The space of *Other* does not have to be Cartesian
Does *Other* need conservation laws?	No. It doesn't need quantities that are conserved, such as energy and momentum.
How much of *Other* is needed to do our Universe?	From an informational perspective, maybe 10^{120} cells in a RUCA for 10^{40} steps.
How big is *Other*.	Again, from an informational perspective, Probably vastly larger than our Universe.
Why is *Other* running our Universe?	The speedup theorem proves that even in *Other*, the answer that will be determined from running our Universe cannot be obtained any

	faster than by doing what is being done.
What qualities must *Other* have?	*Other* must be able to support the creation and operation of a RUCA large enough to do our Universe.
Can we ever learn more about *Other*?	Absolutely! As we better understand what is happening in our Universe, we may be able to understand the nature of the question.
What are some of the additional things we might learn about *Other*?	Once we fully understand how physics works, we can embark on the task of investigating possible purposes for this Universe. We can then compare the size of other similar problems to the scope of this Universe RUCA as an engine that seeks the answer. This gives a tradeoff between the value of the answer and the cost of the resources in *Other*. Thus, we can make intelligent guesses as to what its all about.
Has the puzzle as to the origin of our Universe simply been put off to *Other*?	No. There is no reason to suppose that *Other* needs conservation laws or the concepts of beginnings and ends. Computation can easily occur in Universes whose characteristics leave no mystery as to beginnings or origins.

Where is Other?

Other is not in this Universe. It is not only in another place, it is most likely in another kind of place. If *Other* were a Universe just like ours, but larger, so that its inhabitants might have the resources to simulate our Universe, then no questions would be answered by thinking about that place. The reason is that all the puzzles about our Universe would apply to that Universe. Therefore we assume that *Other* is different and that in *Other*, there is no Cosmogony paradox. As to where *Other* is, this is easy to deal with in the Negative. *Other* is not in this Universe. Given DM is a good model, this Universe is, in some sense, inside of a RUCA. The RUCA is in *Other*. Other is not in a place, as we know the concept referred to by “place”. If we want a statement as to where *Other* is, the following is the best we can do: “*Other* is where the RUCA is, which is outside of our Universe.”

The Artifact Possibility

In our Universe, the largest scale phenomena seem, in essence, somewhat disconnected from the smallest scale phenomena. This is a curious situation. It raises the unlikely possibility that the purpose of the Universe may be entirely in the smallest scale activity, and the large scale aspects are merely an artifact. It's also unlikely yet possible that the Big Bang, as a single singularity in a large QM experiment, is not related to the purpose. While today, all of this is just wild speculation, as we learn more about both the microscopic aspects of particle physics and the macroscopic aspects of the Universe at large, we will keep obtaining more pieces of the puzzle. The main point is that there is no reason whatsoever to suppose that the *answers* to many such questions must remain hidden from us.

What Space-Time Does In One Time Step When Time is Odd

When the time is odd, some spatial neighbors in the Imaginary array may swap places. It is the configuration of the temporal neighbors (all in the Real array) that govern whether or not the swap takes place. Thus, when time is odd, the states of the cells in the Real array are what determine which cells in the Imaginary array will swap places.

What Space-Time Does In Six Time Steps

The RUCA rule is one that has an orientation that corresponds to one of the 6 directions of the coordinate axes. The rule goes through a 6 step cycle where it is oriented to each of the 6 directions in turn. That plus the rule has the effect of putting bits into a small natural orbit unless the neighborhood rule intervenes to adjust what happens. That is the reason why the Bit has the dimensions of Angular Momentum, and is the basis for CPT reversibility.

DM Momentum, Energy, Mass, Charge and Spin

All we have are the **B**'s, yet they have many attributes of physics to represent. We will start with Momentum and proceed to Energy, Mass, Charge and Spin. All of our discussion will be, at this point, what might be called "Qualitative". The Quantitative and Mathematical discussion will be given later. It is a fascinating puzzle to find simple ways that all structure made up of patterns of the B's to represent separately different characteristics of physical systems.

Momentum

We choose to start with momentum. There are several reasons for this. The primary reason is that in physics, momentum has the property of simplicity. It is not only conserved, but it has a straightforward aspect. Linear momentum comes in just one form and the momentum of any system is just the vector sum of the momentum of its parts. In ordinary physics, momentum is mass times velocity.

In Quantum Mechanics, there is a wave associated with momentum, just as there is a wave associated with energy as in photons. The energy of a photon is related to the temporal frequency of the photon. If it is a photon of visible light, then the temporal frequency is related to the color; red photons have a lower frequency and lower energy than blue photons. However, the momentum of a photon or of any other particle is related to the spatial frequency. This means that there is a wave in space, and it has a wavelength. A shorter wavelength means a higher frequency. A longer wavelength means a lower frequency. For photons and any other particles that travel at the speed of light, the momentum and the energy go hand in hand. The momentum is just the energy divided by c, the speed of light. For particles with rest mass, the momentum

Momentum is a vector. That means that it has both a magnitude and a direction. What we want to define is the smallest amount of momentum that is possible in DM. We will define an atom of momentum and explain how it works. If momentum is a wave in space, and space is filled with bits that have simple meanings, then we can imagine a sea of bits spread across space; lots of +B's then after some distance, lots of –B's with this pattern repeating. It becomes clear that the spatial frequency is tied to the regions of spatial transition, where +B's are changing to –B's and vice versa. If one could fly through the microscopic space, the more often this happen the greater the momentum (given that certain other conditions are true). But if we want to find the atom of momentum, we need only look at 2 cells that are closest spatial neighbors. If they are different they are a smallest fragment of a momentum wave. Thus two spatial neighbors that are in different states at exactly the same time are an atom of momentum. Of course, there are several ways that they might be in different states; they might be {–B, +B} or they might be {+B, -B}. Further, the cells in which those 2 B's are resident, also have spatial parity. Thus the atom of momentum is a vector that is aligned with a line through the 2 cells. The determination as to the sign of the momentum depends on the states of the B's and the parity of the cells. Given a volume of space-time with various momentum atoms in it, the total momentum is the vector sum of all of the momentum atoms.

The way that the momentum of a particle changes is for the number of momentum atoms that represent the three momentum vectors to change. Because of the law of conservation of momentum, momentum atoms cannot be created one at a time; they are created in pairs, where the pair has zero momentum. They are also destroyed in pairs. This is one of the mechanisms that enforce conservation of momentum. In general, it is the interaction with force atoms that change the momentum. For a particle without rest mass, the direction of an added or subtracted momentum atom would have to be oriented so as to not introduce rest mass into the particle. This doesn't seem to be a very simple thing to do. But then, particles with no rest mass have no charge and are unaffected by most things that might change their momentum, with the exception of gravity.

What is DM Energy?

Since Energy is a scalar, it is easier to account for than momentum. An energy atom is simply 2 cells that are temporal neighbors that are in different states. We imagine that what is called “empty space” actually has some energy density. Therefore positive energy must rise above the background level. If there is a sea of +B’s and +iB’s, and in the middle of it there is a single –iB, then that would account for 12 units of energy, since the single –iB cell has 12 nearest +B neighbors, each of them contributing being one unit of energy. Of course, this is only one way to account for the energy total. There are different ways and the best way is yet to be determined.

How can B’s make Energy and Momentum?

If there is a sea of +B’s then an added single -B seems to introduce an amount of energy and an amount of momentum, but in many cases (for particles with rest mass) these are somewhat independent quantities. How is this possible? The answer is simple, and it is tied to how the B’s produce rest mass. There is an easy way for a configuration to have energy added to it without changing its momentum. If we add momentum atoms in pairs, each having the reciprocal direction to the other, then there will be no net change in momentum. A pair of momentum atoms whose vectors add to zero, has zero net momentum. On the other hand the energy they contribute adds up. This is the origin of rest mass. It is a property of a particle that has a configuration that involve a number of complementary momentum atoms. The energy of the complementary momentum atoms is the source of the rest mass of the particle.

What is the source of Charge?

Charge is very simple. Every energy atom has charge. The sign of the charge depends on the space-time parity mod 2. Every pair of 2 B’s that are temporal neighbors has a two properties associated with it, one is energy and the other is charge. There is no such thing as energy without charge, however since, like momentum, charge is a vector quantity (the vector has just 2 directions, + and -), it is possible for complex particles to have a standard amount of charge, or no charge at all, since a large number of charges can simply balance each other out.

What is the source of Spin?

At every time state, 2 kinds of neighborhoods become active. The first are those neighborhoods in the array with time coordinate t, that determine whether or not there will be a swap of some other neighborhood in the array with time coordinate t+1. The specification of the orientations of both kinds of neighborhood depends on the time t. It is a function of t modulo 6. Each of the 6 different pairs of neighborhoods differs in its orientations for each of the 6 steps in a cycle. This allows the system to accomplish 2 different objectives: first, things need to be able to move in any direction and second there is the property of spin. In DM, there is no spin around an axis; all spin is orbital. However, during the six steps of a cycle, the effective atom of spin can move through a number of different orbits.

What is the source of Rest Mass?

Particles that have rest mass, have more momentum atoms than just those whose vector sum represents the momentum. This is a consequence of the structure of the particle, where there are, in addition to the momentum atoms that represent the momentum, there are a fixed number that sum to zero momentum. The energy associated with the B's whose configurations result in no net momentum, constitute the rest mass.

In a photon, or other zero rest mass particle, all of the momentum atoms each act in exactly one of 3 orthogonal directions. For example, these might be +X, -Y and +Z. There would be no momentum atoms acting in the –X, +Y or –Z directions. The result is that the particle has momentum associated with its energy, but no rest mass. Thus its velocity can be equal to c, the speed of light. If the DM concept of the origin of Mass is correct, then it immediately resolves a number of questions about the geometry of the RUCA space-time. When one considers a large number of plausible possibilities for the nature of the space-time and the representations of the quantities of physics, it turns out that many of them do not allow for the existence of 3 mutually orthogonal momentum atoms. This can be the case despite the fact that these systems still allow for the representation of any exact momentum. Since the total momentum is the vector sum of all the momentum atoms.

The problem comes up any time there must be 2 momentum atoms that are not either identical or orthogonal. In all such cases there is what we have called frustrated momentum. Frustrated momentum means rest mass.

DM and the Rest Masses of Particles

In DM, a fundamental particle is a stable configuration of bits that has a set of properties. These include charge, spin, QCD color and, in the case of some particles, rest mass. There is a big difference between rest mass and all other quantum numbers. That difference is that all of the properties normally thought of as belonging to a particle, with the exception of rest mass, are accurately described by small integers. In DM, however all properties of every particle can be described exactly by integers; some by small integers (one digit) and others by larger integers (tens of digits). Those other parameters include the momentum of the particle.

has Explain $E=MC^2$

Explain Gravity, as a consequence of Mass

Explain Inertia, as a property of Mass

What is Inertia?

In DM we can define rest mass as frustrated momenta. There are other possibilities.

What is a Wave?

Much of what happens in DM has to do with waves. Waves carry information of various types from particles out into the surrounding space. The basic mechanism for all waves is the idea of a outward spreading phenomena amongst the B's despite the fact that the B's themselves are not spreading. Information is communicated, electromagnetic energy is propagated, electrostatic charge effects and gravity are all related to wave phenomena. A particle is always associated with a wave that travels with the particle. The information as to the velocity of the particle is in the wave structure. It is clear from various experimental results that the wave structure can be quite large compared to the apparent size of particles. While all particles have momentum and energy, it is possible for a wave to have negligible energy. The energy density of space is proportional to the density of energy atoms. An energy wave whose crests have higher that average energy density and whose troughs have lower than average density can have very little associated energy. One can think of the energy of the water in the Ocean in terms of $E=MC^2$ and the mechanical energy of the waves in the Ocean.

The nature of waves in the RUCA is different on 3 accounts. The first has to do with the nature of superposition in a RUCA. The second has to do with the extreme quantization of the local amplitudes. Finally, the third has to do with RUCA reversibility. This is discussed elsewhere.

What is a stable particle?

A stable particle is a particle with rest mass. As discussed earlier, one can think of a photon or other particles with no rest mass as either stable or unstable (from objective or subjective viewpoints). A stable particle is one that can move freely without breaking down into a number of lighter particles. The configuration, which lives in an active sea of all kinds of things going on, must be somewhat impervious to the effects of neighboring blocks of cells which might attack it.

What is an unstable particle?

An unstable particle has the following property. There is a set of configurations of the states of neighborhood cells that, if reached, will trigger the onset of the decay of the unstable particle. Some of the cells associated with the particle may be considered part of the neighborhood however not all of the cells of the neighborhood are part of the particle. With regard to the nature of the set of configurations of the neighborhood cells, at any point in time, the neighborhood has some probability of being in the state that triggers the start of the decay. The evolution of the neighborhood states may, from the local perspective of the particle, be considered totally random. It is not random, since the total evolution of the DM system is deterministic, but it is nevertheless essentially orthogonal to almost everything else that is happeneing. This model is a simple-minded way to account for the fact that an unstable particle always has, in any fixed time interval, the same probability of decaying. Thus, this fact gives rise to the exponential decay seen in radioactive substances.

What is DM Momentum?

Momentum is a vector

It must be an informational construct

The digital representation of motion

There is a digital process

The process must act on the digital information and be the cause of the motion!

What is Energy?

In physics, energy is measured in many ways. In the SI system, it is Joules, in Physics it is often MEV, in the sale of electricity it is kilowatt hours. With regard to the temporal waves associated with particles, such as a photon, the energy is ħ x frequency. Of course, Quantum Mechanics is much more basic than electrical power systems but the detailed interpretation of why and how energy is related frequency is somewhat obscure. Where h (Planck's Constant) comes from and why it has the value it does (6.xxx x 10^{-yy} Joule Seconds) is not only obscure but represents *Magic*. ħ is given to us; we measure it by conducting experiments.

In the SI system, the Units of Energy are $\frac{ML^2}{T^2}$. The energy of motion of a moving body (the Kinetic energy) is $\frac{1}{2}MV^2$ or $\frac{1}{2}\frac{ML^2}{T^2}$. The energy associated with raising an object to a higher position (where it would have more Potential Energy) is Force x Distance. Force has units $\frac{ML}{T^2}$ so Force times Distance has units MLT^{-2} x L= $\frac{ML^2}{T^2}$. All of the dimensional arithmetic works out. It is easy to do. Most engineers and scientists have lived with it all their lives and are very used to it but we don't really know what Mass is. While we have a good understanding as to what length and time are, we do not believe that there is good understanding with respect to physical velocity and acceleration (as opposed to mathematical velocity and acceleration). Unfortunately, the numerous different forms that energy can take complicate the understanding of exactly what energy is. *In* physics, *the concept of energy may be somewhat obscure, it may involve magic, but it is absolutely correct.*

In DM, the concept of energy is perfectly clear, has absolutely no magic, but it may be incorrect. However, as is our object in this entire effort, we are trying to show that perfectly understandable models of physics are possible. The DM units for energy are BT^{-1}.

- ***In SI units it is the Joule, KM^2S^{-2}***
- ***In Quantum Mechanics it is the temporal frequency of some kind of wave.***
- ***In DM it is the temporal frequency of waves of Bits!***
- ***Space-time neighbors in different states constitute the smallest element of a wave.***
- ***In DM, the temporal frequency of the changing B's is exactly what energy is.***
- ***Therefore, there are atoms of energy!***

  In other words, given a discrete system, we can see that the concept of a temporal frequency can be isolated to looking at the part of a wave structure that is transitioning from one state to the other state. What we see there is a place, where it was one state and at the next instant of time it was in the other state. This is both an atom of energy and, for just the transitioning cell, the highest possible energy density. The total energy is simply the number of such transitions above the background level. Empty space is not empty, it has to have some energy density. What we see as positive energy is a higher than average energy density.

Energy

h x Temporal Frequency.

SI=Joule MKS=M^2KS^{-2}, DM=BT^{-1}

The temporal wave number is frequency.

Number of changes per unit time.

Consider a small part of the wave.

An atom of energy is 1 state change between 2 neighbors in time

The total energy is the total number of energy atoms per 6 step cycle.

Electrical Charge

Charge=Energy x Parity
Charge=BT^{-1} x $B^{-1/2}$ $L^{1/2}$ $T^{1/2}$
CPT Parity is a consequence

Charge=$B^{1/2} L^{1/2} T^{-1/2}$
Charge^2=BLT^{-1}
Charge^2/L^2=$BL^{-1}T^{-1}$ (Force= $BL^{-1}T^{-1}$)

Charge

h x Temporal Frequency, SI=Coloumb

MKS=$M^{1/2}L^{3/2}T^{-1}$, DM=$B^{1/2}L^{1/2}T^{-1/2}$

Bit-Length-Time Parity= $B^{-1/2}L^{1/2}T^{1/2}$

Charge=Energy x BLTP

A DM atom of Charge is 1 state change in 1 time step. It equals e/k.

The total charge is the algebraic sum of the charge atoms in one 6 step orbit.

What is DM Force

In DM, force has units B

> Force, as defined by Newton, F=$\frac{dMV}{dT}$, is simply the rate of change of momentum.

DM Quarks, Color and Charge

> Every particle, aside from quarks and gluons, has associated with it information that specifies motion in each of the 3 orthogonal directions. This information is in the form of numbers of momentum atoms for each of 3 orthogonal, absolute directions. Further, there is a corresponding momentum wave structure. Quarks and Gluons are distinguished by having incomplete momentum information. Complete momentum information for hadrons requires that the constituent quarks have, together, complete momentum information. Color actually specifies the quark (or gluon) coordinate information. What this means is that , Blue=x, Anti Blue=-x, Red=y, Anti Red=-y, Green=z, Anti Green=-z. Or Anti Blue=y, z, Blue=-y, -z, Anti Red=x, z, Red=-x, -z, Anti Green=x, y, Green=-x, -y. The first set is associated with charge 1/3 quarks while the second set is associated with charge 2/3 quarks. Thus, whenever a particle is made up of 2 or 3 quarks so as to have an integral amount of charge, it also carries the capability of motion in 3 dimensions. An isolated object, such as an individual quark, that has fractional charge does not have the informational capability of motion in 3 dimensional space. Thus it is limited to composite systems that have both integer charge and 3 dimensional momentum information.

The question as to whether or not a quark is a particle as opposed to just a part of the machinery of a hadron is an interesting one. We are inclined to suppose that quarks will end up being thought of as just part of the internal machinery of hadrons.

What Might a Particle Be?

A charge-spin core, surrounded by the momentum and energy nucleus, N, surrounded by a very much larger momentum information wave structure, W.

There are three ranges of information in a particle that make very different demands on the structure of the particle:

The small magnitude quantum number aspects; this includes what particle it is, the charge, spin, internal energy state. We will give an example where we indicate the integer used to describe each aspect. These integers are typically 1 digit numbers. We will categorize a Muon.

Possibilities	Number of choices	Choice
Boson or fermion (integer spin, such as a photon, or ½ integer spin such as an electron).	2	fermion
Member of the lepton family or quark family	2	lep

		ton
Electron family or Neutrino family	2	electron
Generation: 1 (electron, d u), 2 (muon, s c), 3 (tau, b t)	3	muon
Charge magnitude 0, 1/3, 2/3, 1	4	1
Particle or Antiparticle (sign of charge)	2	particle
Spin (with regard to a measurement)	2	up
Choice of which particular true rest mass	≈ 11	m_{μ}

The medium magnitude number. There is only one, and that is the magnitude of the true rest mass. The true rest mass is just the number of frustrated momentum atoms or other atoms that each have a smallest unit of rest mass. The measured rest mass of a particle might differ somewhat from the true rest mass because of the mass associated with some form of internal energy. We believe that all rest mass magnitudes can be represented by 11 or 12 digit numbers at most. For an electron, the number might be as small as, say, 13 units of true rest mass. This would mean that a Muon would have 2688 units of true rest mass. On the other hand, the number of different true rest masses, for all the primitive particle types is a small magnitude number approximately 11.

The large magnitude numbers: This includes energy, momentum, half-life… all the aspects that have many possible values. We know that current measurements do not reveal quantization. Nevertheless, we should not be misled. Experiments that might show quantization have not been designed to be sensitive to the kinds of effects that are a consequence of the DM theory.

In DM, the representation of the information is digital. That means that there must be informational constructs that carry the meanings of the values. The operation of the RUCA, in effect, must translate those meanings into the specified actions. In the case of numbers that have a wide range of possible values, we have to consider what number system will be used to represent the meanings. If, for example, the number system were binary, then there would be a need for doing binary arithmetic so that during an elastic interaction between two particles, the energy and momentum would both be conserved. The use of binary representation has certain difficulties, in particular, it is hard to see how the kind of superposition so much a part of physics, could be handled. If the information is in the unary system, then the +x momentum of a particle would be equal to the number of +x momentum atoms associated with the particle. Thus conservation of momentum in an elastic collision between two particles, simply means that all the momentum atoms that were in the two particles before the collision were redistributed between to two particles after the collision, with nothing lost. The redistribution must follow the law that no particle gets any momentum atoms in direct opposition other than the re rest mass. Of course, there can be other models for rest mass.

The Impetron, Impeton, Pushon or Momenton is the DM-Atom of linear momentum.

The Elan or Energon is the DM-Atom of energy.

The Osmotron is the DM-Atom of force.

The Chargicle is the DM-Atom of charge.

Compare MKS vs DM -- Score

Mass	M	$BL^{-2}T^{1}$	-3	
Action	$ML^{2}T^{-1}$	B	3	
Energy	$ML^{2}T^{-2}$	BT^{-1}	3	Bit temporal frequency!
Charge	$M^{1/2}L^{3/2}T^{-1}$	$B^{1/2}L^{1/2}T^{-1/2}$	1½	
Force	MLT^{-2}	$BL^{-1}T^{-1}$	1	Bit space-time frequency!
Momentum	MLT^{-1}	BL^{-1}	1	Bit spatial frequency!
Power	$ML^{2}T^{-3}$	BT^{-2}	3	
Pressure	$ML^{-1}T^{-2}$	$BL^{-3}T^{-1}$	-1	
Viscosity	$ML^{-1}T^{-1}$	BL^{-3}	-1	Bits per unit volume!
Rotate Inertia	ML^{2}	BT	1	

Note: B is already quantized!

Total: DM by 8½ points.

CPT -- If time is reversed

Matter becomes Anti-Matter

Positive charges become negative

Negative charges become positive

Color becomes anti-color

$\mathcal{L}$ The *Landauer* Constant

A Fundamental Constant of Nature
When a Shannon Bit is erased, then…
An amount of energy must be dissipated
The Amount depends on the absolute temperature
The formula, due to Rolf Landauer is:
Energy/(Shannon Bit)=Log 2 k T = $\mathcal{L}\mathcal{T}$
$\mathcal{L}$, is the *Landauer* constant
$\mathcal{L}$ =Log 2 k (Boltzman Constant)
$\mathcal{L}$ =9.567x10^{-24}Joules/Degree Kelvin

Using $\mathcal{L}$ to define temperature

B_s = Shannon bit
B_d = Binary digit
B_s/B_d = Information in a binary digit
Information flowing out from a large space.
We know the average energy/B_d
$E/B_d = B_s/B_d\ \mathcal{L}\ t$ (here, t is temperature)
$t = E/(\mathcal{L}\ B_s)$

The BBM and Maxwell's Demon

It is possible to construct a BBM circuit that gives an interesting insight into the Maxwell's Demon problem. The number of constructions that have been thought up to try to shed light on this problem is quite amazing. We won't go through the history, but just give a quick discussion of the Demon as implemented in the BBM. The idea is that there are 2 spatial regions, each with a somewhat sparse density of Billiard Balls. The circuits are arranged so that the 2 spaces both join as 2 inputs to a conservative logic gate. The third input to the gate controls whether the 2 inputs are passed through straight or are swapped. This is like the function of the trapdoor that is controlled by the demon. When the trapdoor is open, a billiard ball that is heading for the trap door can pass through, in either direction. In this case, all we ask of the demon is to try pack most of the balls into the same space. There are 2 cases where is doesn't matter what is done with the trapdoor: 1st, if there is no billiard ball coming from either space, and 2nd, if there is a ball coming from both spaces. The demon's job is to create a region of high density and a region of low density out of two regions of equal density. As the high density region gets more billiard balls packed into it, then the probability of a billiard ball from the high density region heading for the trapdoor increases. Of course when this happens, the Demon must keep the door closed. And only open it when a ball heads for the trapdoor only from the low density side.

There is a lot of nonsense about the problems of bouncing photons off of molecules in order to tell when to open the trapdoor. We can allow our demon to have complete knowledge of everything about the comings and going of billiard balls, without disturbing anything and he can easily pack most of the billiard balls into one of the 2 regions, but nevertheless, he cannot lower the total entropy!

Of course, all properly constructed BBM circuits have the property that they are perfectly reversible. So after working at the task of packing the balls into a high density region, if things are put into reverse, the events must exactly retrace their steps going backwards. That means that the process going forwards must not lose the information necessary for things to be able to go backwards. Of course, the BBM has the property that every well formed circuit is always perfectly reversible, so all such circuits also have the property that there is no loss of information.

The fact that the system is reversible is sufficient to prove that the Demon cannot reduce the total entropy.

Let us consider what the Demon has to do when the system is in reverse. Say the demon sees a billiard ball in the high density region heading for the trapdoor. Should the demon open the door to let it pass into the region of low density? The answer is that he must do so if, when time was proceeding forwards, the door was open and the ball passed from the low density region to the high density region. The demon must keep the trapdoor shut if when going forwards there was no billiard ball passing from the low density region to the high density region; rather a billiard ball from the high density region had just bounced off of a closed door. In our simple model, there is no way that the demon can figure out what to do by looking at the billiard balls. The only possible solution is for the demon to remember what he did when running forwards. In other words, if the model is to be reversible, the demon must remember, when going forwards in time, for every billiard ball that is flying away from the trapdoor region on the high density side, whether or not it is flying away because it passed through an open door or because it bounced off of a closed door.

The magic is that the decrease in entropy that results from packing the billiard balls into a high density region is exactly matched by the increase in entropy inside the memory of the demon, as he must remember enough to allow the process to proceed reversibly.

In the actual BBM circuit, the memory of the demon is a necessary part of the machinery that allows the demon to function.

It is interesting to consider the case where the balls ome in 2 similar types. For example, consider a gas filling both chambers, 50% He (Helium 4) (molecular weight approximately 4) and the other made up of Deuterium D_2 molecules (molecular weight approximately 4). Assume the object is for the Demon to get most of the D_2 on one side and most of the He on the other side. In this case, the Demon need not remember anything in order to have the overall system be perfectly reversible. We assume that the Demon can see each molecule approaching the trap door, and can identify which kind of molecule it is. Of course, just leaving the trapdoor open will eventually accomplish the same thing but the use of a reversible demon will greatly speed up the process, expecially after equilibrium is near!

The RUCA & Informational Rigidity

We have no natural familiarity with systems like RUCAs. What we have observed is a kind of behavior that is surprising but not outside all of our experiences. The best analogy to the property we call RUCA Rigidity is a system of interconnected gears as in a simple clock. When one gear turns, all gears turn. You can turn a gear in one direction or the other. When you reverse the direction of the gear you are turning, all other gears reverse direction. There is no possibility of arranging the position of the gears independently. Further, if each gear has a prime number of teeth, and no two gears have the same number of teeth, then the whole system will take an amount of time related to the product of all the primes, to return to its original state. In such a system it makes little sense to imagine one gear being put into a particular state, independently of all the other gears. Finally, imagine a magic gearbox with one shaft here and now, and another shaft somewhere else and later. If we turn our shaft here and now, the other shaft turns there and later. However, imagine this difficult thought, what if our magic also worked as follows: There and later someone turns the shaft and as a result, the shaft here and now twists! This is beyond our normal experiences, but is the way all RUCAs work.

The RUCA is totally interlocked in space and time. Of course it is much more complex than a set of gears and the consequences of its activity is much harder to understand, nevertheless it is still like a set of interconnected rigid parts, none of which has any independent freedom. Finally, unlike ordinary thermodynamic processes, where entropy is increasing, the RUCA always makes perfect sense whether it is going forwards or backwards. At the microscopic level entropy is always conserved by the operation of a RUCA. This means that the concept of cause needs to be replaced by a new, time symmetric concept, which we call RUCA Informational Rigidity.

Let us assume that we have a particular RUCA and that it is a system that will cycle in S time steps. We have defined $I=\mathrm{Log}_2 S$ as the measure of the total Information content of the RUCA. I is a conserved quantity since in theory, it can always be calculated from any point in time and the calculation always gives the same value. Let us consider the smallest change that can be made to a RUCA. Imagine that we simply change one bit somewhere in the RUCA. Then there are exactly 2 possibilities for the consequences:

The value of *I* does not change. This outcome has an infinitesimal probability of happening. But what has happened is that the RUCA has taken a potentially enormous leap to another point in time. Compared to the total time for the RUCA to cycle, the leap is equally likely to be almost anywhere other than nearby its previous temporal position.

The value of *I* does change. This outcome has a probability very close to 1. In this case we move to a completely different computation. The outcome will certainly be grossly different. A divergence will spread from the changed bit, at the speed of light, very likely propagating a new region, possibly with different laws of physics.

There is no place in a RUCA for statements such as "Let us arrange for state *u* to happen at x, y, z, t." If *u* does happen at x, y, z, t it's not because we decided that it should. It's because the entire Universe conspired to make it happen. Just as we believe the past to be deterministic, in a RUCA, so is the future. However it shares one important aspect with Quantum Mechanics. There is, in general, no way to predict the future! We call it "Unknowable Determinism". Not only is the future hidden from us, it is clearly hidden from every possible thing or process that is within the RUCA. It is the nature of the whole process that from within the system there never is the possibility of knowing any exact macro state (the exact state of some substantial region of space-time) before it happens. The reason is a practical one. There is no way to, from within the RUCA, to get access to all the information that would be needed. If we had all the information, there one would have no way of processing it to see the future before it happened.

Everything that makes sense when a RUCA is proceeding in the forwards direction must also make sense when proceeding in the reverse direction. When looking at a RUCA model of some event, such considerations are a powerful analytical tool. For example, we can point to situations where what is clear and seems to be good physics going forwards, is mystifying going backwards. If one is correct about the forwards situation, then the reverse is good physics no matter how mystifying it is. What is much more interesting is that we will discuss a situation that makes little sense going forwards, but makes better sense going backwards. What all this means it that there is a new avenue that can be use to gain understanding of processes in physics. We can look at what is happening in the reversed time direction, and as we shall see, that act, along with the principal of Informational Rigidity has the potential to clarify situations that might otherwise be obscure.

EPR – Bell's Inequality

There are a series of hypothetical and actual experiments related to measurements made on two separated particles in the singlet state. In such cases the predictions of QM seem at odds with the concept from Relativity and common sense that there is no action at a distance. This issue has been made much clearer by Bell[25]'s paper and by a model due to Mermin[26] where it is shown that given the results correctly predicted by QM one must give up the principle of locality. DM is a model of physics based on absolute locality. Does that mean that DM is simply wrong, as verified by experiment?

The answer is "No." The reason is difficult to understand. It might be explained as a consequence of RUCA Informational Rigidity. What we believe is that there is another property to nature that is currently unappreciated. It is a property of discrete reversible systems, where almost no one has any experience. The nature of all such systems is that at the most microscopic levels there is perfect reversibility along with various conservation laws, despite the extreme quantization that is characteristic of a RUCA. The result is that certain kinds of behavior are exhibited that are both unfamiliar and counter intuitive. Among these different behaviors are the appearances of unintutitive correlations that appear in different parts of a seemingly random background. Further, there is the property we call Informational Rigidity. What this means is that events are not only linked to the past, but are similarly linked to the future. An informational act in the future can have the same consequences as the same act in the past.

A RUCA is a Digital Informational Process. All of the properties we ascribe to physical entities are manifestations of the RUCA Informational Process. When we conduct a QM experiment in the DM model, and we wish to understand what is local and what is not local, it is necessary to take into account Informational Rigidity. The definition of Informational Rigidity is:

Consider every process with parts separated in space-time, where something that happens in place and time A is said to affect what happens in a distant place B and at a later time (because of speed of light limitations). Informational Rigidity requires that if that affect is true, then there is another true statement that can be made about all such systems: Whatever happens in place B at the later time can be said to affect whatever it was that happened in place A at that earlier time.

Informational Rigidity is a concept that is apparently foreign to all our experiences, with one exception that the author knows of. The exception is the careful scrutiny of various working RUCAs and a few other abstract mechanisms.

We are used to thinking about probabilities and how they work; our intuition is usually a good guide. It seems obvious that there is one chance in four that you will draw a heart from a deck of 52 cards. If you shuffle the deck and draw again, there is still one chance in 4 that you will draw a heart again. Therefore the probability that you will draw a heart, each time from a full shuffled deck, twice in a row is ¼ x ¼ which is 1/16. On the other hand, while the probability of drawing a heart is ¼ and the probability of drawing a diamond is ¼, the probability of drawing a red card is ½. In the first case we multiplied the probabilities and in the second case we added them.

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[25] Give reference to Bell's paper on "inequality"

[26] Give reference to Mermin's paper, that Feynman liked.

We have learned to do similar sorts of computations in Quantum Mechanics. However the method of calculation is not intuitive. Instead of working with probabilities directly, we calculate with amplitudes. While a probability is a number between 0 and 1, an amplitude is a complex number. It can be thought of as an arrow that points in some direction and that has a length. To correctly calculate a probability in QM, we first calculate an amplitude and then we take the square of the absolute value to get the probability. That is like measuring the length of the arrow and then taking the square of that number. It sounds weird but it works and it gets the right answers. For example, a probability of $\frac{5}{8}$ could be the consequence of an amplitude of $\left(\frac{1}{4}+i\frac{3}{4}\right)$. The square of the absolute value of a complex number is just the sum of the squares of the real part and the imaginary part. $|a+bi|=\sqrt{a^2+b^2}$ therefore $|a+bi|^2=a^2+b^2$

From the Quantum Mechanical point of view, we have also learned that we cannot analyze particle interactions by looking at one particle at a time. Instead, we must consider amplitudes for various events, including all of the particles that are involved. A proper quantum mechanical statement might be (assuming low enough energy so that no particles are created or annihilated):

Assume we want to calculate the probability that some present state, $S_{1,}$ will lead to some future state, S_2. We abbreviate this using Dirac's notation "$<S_2, S_1>$". The *approximate* normal process is, in effect, to calculate the amplitudes for the possible steps that connect S_1 and S_2. We combine the amplitudes by adding or multiplying depending on whether we are dealing with alternative amplitudes or sequential ones. When we have the overall amplitude for the total event, including all the involved particles, we take the square of the absolute value to calculate the probability of the event.

When we look at the experimental apparatus designed to test Bell's Inequality we see features common to all such systems:

1. There is the production of 2 correlated particles, p_1 and p_2 in place a_1, time t_0.
2. An *Independent* event is used to set the filter angle: f_1 at time t_1
3. Another *Independent* event is used to set the filter angle: f_2 at time t_2.
4. Correlated particle p_1 arrives at f_1 at time t_3.
5. Correlated particle p_2 arrives at f_2 at time t_4.
6. Information is gathered at f_1 at time t_5 that indicates whether or not p_1 arrived at the detector.
7. Information if gathered at f_1 at time t_6 as to the filter angle
8. Information is gathered at f_2 at time t_7 that indicates whether or not p_2 arrived at the detector.
9. Information is gathered at f_2 at time t_8 as to the filter angle
10. The information about the partial result of the experiment at f_1 (filter angles and pass through or not) is sent at time t_9 to the site, s_1, for analysis.
11. The information about the partial result of the experiment at f_2 (filter angles and pass through or not) is sent at time t_{10} to the site, $s_{2,}$ for analysis.

12. The information at s_1 and s_2 are both entered into the same informational process in order to determine the statistical results.

We believe that, in a well designed experiment, steps 2 and 3 are independent, with no possible correlation. If somehow, there was some informational path that correlated the settings of f1 and f2, it would affect the outcome of the experiment. Gedanken experimenters go to imagined great lengths to insure a lack of such correlation. They resort to such ideas as using starlight from a distant star on the side of the Milky Way Galaxy to the left to set the filter on the left side, while light from another star on the other side of the galaxy is used to set the other filter on the other side.

The main problem that DM illuminates is that in doing such experiments, we imagine something that cannot be true. That is that we imagine that an initial state just happens, and is in some way uncorrelated with other events in the past or the future. In DM we see that nothing ever *just happens*! Whatever happens is a consequence of the fact that the whole Universe conspired, since the beginning of time, to make that exact event happen, along with whatever future measurement might be taken. This is the nature of the Informational Rigidity of all DM systems.

In any case, while Einstein, Podolsky and Rosen dreamt up the so-called EPR experiment to point out the fact that QM seemed to be making ridiculous predictions, Alain Aspect produced results that support the ridiculous predictions of QM. What DM tells us is that the mathematics of DM works and is accurate, but that the English Language (or Danish, French, etc.) in vogue descriptions of what is happening is plain nonsense. In other words, in DM we can have an explanation of the results of physical experiments that totally avoids any action at a distance.

Instead of imagining 2 photons in the singlet state (correlated spins) let us think about a different process. Imagine we have a process that creates an electron-positron pair, with some energy that results in them flying apart. Further, let us imagine that there is a magnetic field perpendicular to the direction of motion. Both particles will travel in a circular arc; one going clockwise and the other counterclockwise. A common interpretation of QM would be that when we measure one of the particles as to spin state, that measurement would determine the spin state of the other particle; regardless of the distance to the other particle. What about the charge state? If we detect one particle and discover that it is positively charged, is that what determines, at that instant, that the charge of the other particle is negative? There are a number of reasons why such a hypothesis seems to be absurd.

The quantization of space and time open the door to other possible explanations for Bell's theorem.

And now, with the perspective of informational rigidity, we take a look at the time reversed version of the same event.

- 12. The statistical results are run in reverse to obtain the 2 resulting information sets. Both are removed from the same informational process and sent to s_2 and s_1.
- 11. The information about the partial result of the experiment at f_2 (filter angles and pass through or not) is sent from the site for analysis to arrive at f_2 at time t_{10}.
- 10. The information about the partial result of the experiment at f_1 (filter angles and pass through or not) is sent from the site for analysis to arrive at f_1 at time t_9.
- 9. Information at f_2 at time t_8 is to be used to set the f_2 filter angle.
- 8. Information at f_2 at time t_7 is to be used to decide whether or not the detector emits p_2 or whether the filter emits p_2.
- 7. Information at f_1 at time t_6 is to be used to set the f_1 filter angle.
- 6. Information at f_1 at time t_5 is to be used to decide whether or not the detector emits p_2 or whether the filter emits p_2.
- 5. Correlated particle p_2 leaves f_2 at time t_4.
- 4. Correlated particle p_1 leaves f_1 at time t_3.
- 3. The filter angle, f_2 is set from the information on hand at time t_2. Then the supposed independent event is generated at f_2.
- 2. The filter angle, f_1 is set from the information on hand at time t_1. Then the supposed independent event is generated at f_1.
- 1. There is the arrival of 2 correlated particles, p_1 and p_2 in place a_1, time t_0 where the process that created them gets undone..

What we see in the time reversed steps 11 and 10 is that the information arriving from the place where the data analysis was done (and where the information about the 2 filter angles was definitely commingled) arrives at the 2 filter sites. Reversed time steps 9 and 7 use this commingled information to set the 2 filter angles. Further commingled information is used to determine which filter passed the photon (and in reversed time it is reemitted from the detector) and/or which filter absorbed the photon (which in reversed time has to emit it.

In Reverse time we have had to violate the rules that caused us to want the filter positions to be uncorrelated. Interestingly, there is no way to analyze the data without bringing both the filter positions and the detector results to the same place for analysis. Informational Rigidity has to do with correlations imposed by the informational process. It doesn't matter how the information gets communicated. It could travel down a fiber optic cable, or it could be written on a floppy disk, set aside for a few years, and then brought together in order to do the calculations. Both examples have the same degree of Informational Rigidity.

Rest Mass

In normal physics, the 3 most basic quantitative properties are Mass, Length and Time. While the choice of basic units is somewhat arbitrary, but there has never been a good reason to overthrow M, L & T. These constitute the 3 most basic units. Most other units can be reduced to combinations of M, L & T. For example, the dimensional units of momentum are MLT^{-1}, and those for energy are ML^2T^{-2}. In DM we do not need to include Mass as a basic concept. Of course, in DM we will know what mass is and we should be able to measure the rest mass of a particle. However it is not a Unit or Dimension of the DM Theory. Instead, we define Mass as follows: $M=BL^{-2}T$

The Problem of Moving Slowly

The wavelength represents the total energy and the size of the generating structures must increase as the particle moves more slowly. If the particle had no rest mass, the wave structure would become infinitely large as the particle came to a stop. Imagine that the momentum information of a particle with rest mass represents the rest mass as frustrated momentum (some momentum in one direction and other momentum in exactly the opposite direction). This would allow the particle to come to a stop with a finite size related to its total energy. Further, this is an explanation as to why all particles without rest mass move at the speed of light and why only particles with rest mass can have variable speed.

Empty Space

Background. In DM, so-called "empty space" is certainly not empty. It has a basic energy level and it can be excited to propagate waves. An energy atom has 2 possible temporal phases. These correspond to the + and – of electrical charge. Every energy atom can and does propagate waves into the medium. Of course, the energy atoms excited as part of a wave, also propagate waves. Energy and Momentum go hand in hand. There can be momentum structures that have no momentum because the vector sum of them all equals zero. On the other hand, energy is a scalar that is additive. That is true for charge also, but there can obviously be a balance of + and – charges that balance out to create an energy structure with zero net charge.

We assume that the average energy density of so-called "*empty space*" is some fraction of the maximum possible value. A look at the state of a small volume of *empty space-time* would show charges, momentum vectors and energy fluctuations. All of this is a consequence of the fact that a pattern of bits has interpretations that reflect all three. Energy waves can propagating through the medium can provide a model for gravitational effects.

Charge Interaction.

What goes here??????

The Spatial and Temporal Structure of the RUCA

We will give 2 different models of RUCA to illustrate concepts of Digital Space-Time. Both are Cartesian Lattices, but with 2 different structures.

The first is a simple 4 dimensional space-time Cartesian lattice. Every cell has 4 integer coordinates, t, x, y and z and every distinct set of 4 integer coordinates denotes a unique cell. Nothing ever moves or changes within a time cube (space at a given time). The process of physics takes place as follows: A value of time, call it t_0, is considered to be the present. A function over local neighborhoods at time t_0 is computed for each neighborhood. The results are then used, along with the t_{-1} cube (the past) to determine the state of the t_1 cube (the future). The deciding function over the t_0 array and the swapping function of the t_{-1} cells to the t_1 cells is called r_j (*rule* j, where j has the value 0). In general there are a limited number of *rules* that are very similar, but rotated into different orientations from each other. In our example, j=t Mod 6; j only takes values from 0 to 5, meaning there are six different rules. The t_1 (future) cube is identical to the t_{-1} (past) cube except that certain bits have been swapped (2 neighboring bits have changed places) in those neighborhoods as determined by the neighborhood function in t_0 (the present). Further, the cells are colored red or black according to the parity of the coordinates. The parity is a factor in the rule. From an informational process point of view, there is never any need for the presence of more than 2 cubes at neighboring points in time. The present determines how the past will change into the future. When we have finished changing the past into the future we re-label the present as the past, then we re-label the future as the present and start the process over again but using the next rule in our cycle of 6 rules.

The second is similar but the cells are laid out differently. Again, each cell has 4 integer coordinates. However, the space consists of a single cube that encompasses 2 time states as FCC sub arrays. As mentioned before, the design is much like a crystal of ordinary table salt, NaCl.

The 7 Fundamental Constants in DM

Strangely enough, in the DM theory of physics there are exactly seven constants, and all but 3 of them are small integers. Almost all of the small integers are various fourth roots of 1. The three units of DM, ***B***, ***L*** & ***T***, are all constants of the theory and all have value 1. An example of a constant of the DM theory is the number of space-time dimensions, which is 4. In ordinary physics Mass, Length and Time are dimensional units and the kilogram, meter and second are arbitrarily defined amounts set as International Standards (SI). In DM there are the 3 basic Units ***B***, ***L*** & ***T***. There is no need for any arbitrary definitions of an amount of ***B***, amount of ***L*** or ***T*** because they are absolute Units. Thus the Unit of Length is 1 ***L*;**. the Unit of Time is 1 ***T*** and the Unit of Bits (also the Unit of angular momentum and action) is 1 ***B***. There are only 7 fundamental constants in the DM theory and 2 of them are integers representing a set of binary digits whose magnitude has no significance. Of the three large integers, one them is the rule that animates physics by driving a process which causes the representations of states to evolve over time. This can be reduces to nothing more that a simple algorithm or computer program (which can be thought of as a large integer and thus a constant of Nature).

The 7 fundamental constants of DM are far more inclusive vis-à-vis the evolution of the Universe then anything comparable in ordinary physics. In theory, given nothing more than the values of the 7 fundamental constants of DM, an alien

(alien to our universe) who had a large, fast computer at her disposal could recreate the entire universe we live in, exact in every detail. This could range from the beginning of the big bang, through today's current events on Earth ("Tiger Woods wins the 100th US Open Championship by 15 strokes.") and on to the exact future that is unknown and unknowable to us.

The *Rule*. The first constant is the definition of the Rule. This includes the nature, size and connectivity of the RUCA. The exact definition is simply a program for some standardized RUCA that causes that host computer to carry out the same computation as DM. Of course, the program will be different for different host computers. Since a typical computer program is a list of instructions, each of which is a binary number, the whole set of them can be represented exactly by a single large integer. The size of the *Rule* will undoubtedly be no more than about one kilobyte. However, the nature of the *Rule* will have a profound effect on the size of the *Start*. A criterion for a good Rule is that the sum of the number of bits in the *Rule* plus the number of bits in the *Start* should be minimized. The magnitude of the integer that is the *Rule* is has no meaning. We single out the space-time dimensionality (4) as a separate Constant, number 7, even though it is explicitly a part of the *Rule*. Today, there is no agreed upon language in which to write the *Rule*, but that can be easily remedied.

The second is the *Start*, the definition of the initial conditions. This is the precursor to the Big Bang. It is essentially a pattern of **B**'s that defines the initial conditions. Since each B is just a Bit, the set of bits that define the initial conditions can be represented by an integer. However we define *Start* to be a computer program that generates the integer. The initial conditions may control much more than one would normally realize, as the very kind of physics in DM may depend on the initial conditions. In other words, there are many possible DM rules that have the property that the very laws of physics depend on the initial conditions. For a RUCA with given behavior, there is no fixed boundary between initial conditions and the definition of a RUCA. The exact behavior, or behaviors isomorphic to it can be often obtained by complex rules with simple initial conditions or by simpler rules with more complex initial conditions. The Banks rule for a 2 state von Neumann neighborhood UCA, which is the simplest known UCA, requires that the entire space be populated with a wallpaper like design as part of the initial conditions. For a given physics, the initial conditions depend on the *Rule*. In fact, if any RUCA can exactly do physics with the proper initial conditions, then every RUCA can also exactly do physics with the proper initial conditions specific to that rule. The choices are a matter of esthetics and economy. Many combinations of RUCA design and initial conditions are very complex and/or very wasteful of computational resources. Others are very concise in terms of definition and initial conditions. Finally, the various RUCAs are more or less efficient in the execution of the physics which is a consequence of the RUCA rules.

In DM we give an example of a particular RUCA and of the form that elements of physics takes in the RUCA. Interestingly, the integer that represents the initial conditions could be very small, representing a simple seed of a small number of special bits in an easy to describe sea of bits that fills the rest of space giving rise to everything that follows. On the other hand, *Start* might be as large as to specify every B in the entire Universe as it is now constituted. The evidence for the Big Bang seems to favor some kind of small seed over defining everything. In a sense these possibilities are very similar to those suggested by Creationists as opposed to those who believe the Theory of Evolution. While Occam's Razor gives great support to the Theory of Evolution, the Creationist viewpoint is obviously self consistent. However it strains one's intellect to imagine why the Universe started out with a *faked* record of ancient events. The same can be said for the origin of the Universe. The most simple and logical models involve a beginning that is far simpler than what now exists.

It may not be possible to ever know the exact value of *Start*, but there may be clues. The most obvious would be the discovery of a very simple Start that results in the laws of physics as we know them while heading in the right direction.

The unit of Length *L*. The unit of length is a constant of the theory with a value of 1. Obviously, it has a metric equivalent that might be somewhere around a fermi (10^{-15} meter, with a very large uncertainty). *L* is the distance from one cell to its nearest neighbor. While *L* is the smallest length in DM, not every length is a multiple of *L*.

The unit of time *T*. The unit of time, *T*, is one step in the evolution of state of the DM RUCA. The *T* is a constant of the theory with a value of 1. While the ratio *L/T* is necessarily related to the speed of light, there may be a small constant, v, involved in the relationship. Thus c=v*L/T*. v is not a constant of DM as it is derivable within the theory.

The Bit *B*. The unit of the Bit (and the unit of angular momentum) is *B*. The unit of the Bit is a constant of the theory with a value of 1. The unit of *B* is a constant of the theory with a value of 1. While the value of *B* will obviously be related to ∇ there may be a small constant, u, involved in the relationship. Thus ∇=u*B*. u is not a constant of DM as it is derivable within the theory.

The Time (what time it is in DM time, which starts at zero when the big bang occurs). *The Time* is an integer that is counting up. It counts up by 1 for every unit of time. Of course, *The Time* is not a constant as it is always counting up. Nevertheless, it is a fact of Nature which we can approximate and which we can determine with ever increasing accuracy as we learn better measure the age of the Universe with increasing accuracy. In DM, *The Time* modulo 6 is a significant part of the theory. The magnitude of *The Time* tells the age of the Universe. The current value of *The Time* tells us the current date and time in absolute terms. *The Time* is an application for the concept of "integer" that is more familiar to non-computer types; its meaning is the same as its magnitude . *The Time* is always an integer number of units of time.

Although technically a part of the first constant, the *Rule*, we include the dimensionality of space-time, D, as one of the constants. D=4.

Why the SI c and *ħ* are Not Fundamental in DM

Theoretically, all other so-called constants of physics must be derivable from the DM model. From the model, it is theoretically possible to calculate from scratch the DM unit of time. However the current definition of the second, although immeasurably simpler than the old definition based on the mean solar day, may still be too complex for a straight forward from scratch calculation within the DM theory. From a practical point of view, it should not be too difficult to redefine all SI units in terms of the 3 basic DM units, *B*, *L* and *T*. For example, theoretically, the DM model should allow the calculation, from scratch, of the mass of the electron in DM units. Since we know the mass of the electron in SI units we could relate the DM unit of mass **M=1 BL^2/T** to the SI kilogram.

In DM, it will be theoretically possible, given just the rules, to calculate from scratch the SI values of *c* and ħ. To illustrate why this is possible, consider a very large computer running a DM simulation. Given good initial conditions, particles such as photons and electrons would appear in the model. By running the DM model, it would be possible to calculate the results of experiments that measure *c* and ∇. Of course, there is no rule against being able to do a theoretical calculation, based on the DM model in order to arrive at better results.

First is ***B*** (the same physical dimensions as Planck's Constant, and within an order of magnitude of the same value).

The second is ***L*** the RUCA unit of length. It is the distance between nearest space-time neighbors in the Cellular Space and also the smallest effective distance in DM. All points in the DM RUCA space-time have 4 integer coordinates for x, y, z and t. Each integer coordinate for x, y and z is in units of *L*. Each integer coordinate for the *Time* is in units of *T*.

The Bit **B** is essentially Planck's Constant, ħ. It has the same SI units as ħ (in SI ML^2/T) and approximately the same value. However, its significance is not only that it has the dimensions of angular momentum, but further that it is ***B***, the *Bit*. Just as a measurement of a particle's spin is a 2-state system, so is ***B*.** The relationship discovered by Planck, that the energy of a photon is Planck's Constant times the frequency as at the heart of the DM concept of ***B***.

DM Atoms, Particles and Waves

In DM there are many wave phenomena. Energy, Momentum and Electromagnetic waves are primary. What is unusual about waves in the DM model is that all wave phenomena have the property that there is an associated atom. In other words, there is a momentum atom, an energy atom and a charge atom. These are not the only such wave-associated atoms.

Energy Atoms

Energy is represented by a temporal wave. What this means is that at a given x, y, z location, the states of cells, over time, change with some temporal frequency. This may be a coherent wave or an incoherent wave. The frequency of the energy wave in some space-time volume is proportional to the number of cells in that volume that change state. One cell that changes state in one unit of time is an atom of energy! There are many ways of looking at this situation. For example, consider very simple RUCA with a sea of bits, 50% ones and 50% zeros. Assume there is a temporal wave with a frequency ¼ of the maximum possible frequency. That means that ⅛ of the time, an average cell changes from a 1 to a 0 and that ⅛ of the time it changes from a 0 to a 1. The rest of the time it is static. The energy is at the temporal boundary between 1's and 0's. However that is equivalent to the concept of energy atoms. A cell that is undergoes a 1 to 0 temporal transition or a 0 to 1 temporal transition is an atom of energy, *E*. Obviously, energy is a scalar quantity and the energy atom, *E*, is the unit of energy. The energy density of an energy atom is the highest possible value of energy density, 1 change of state in 1 unit of time. All energy atoms are charged, as will be discussed below.

The DM RUCA is a cubic array made up of 2 FCC arrays: the real array and the imaginary array. The time coordinate of the Real array is even while for the Imaginary array it is odd.

Charge Atoms

In DM an atom of charge is simple an atom of energy. All energy atoms have charge. However the nature of the energy atom determines whether the charge is positive or negative. When a –B transitions to a +iB or a –iB transitions to a +B we have a positive charge. When a +B transitions to a –iB or a +iB transitions to a –B we have a negative charge. A zero is added for a The unit of charge

Momentum Atoms

Momentum is represented by a spatial wave. What this means is that at a given time the states of cells, over a region of space, change with some spatial frequency. This may be a coherent or incoherent wave. An atom of momentum consists of 2 adjacent cells that differ in state. The 2 cell atom can represent either no momentum, or the space-time-state parity allows an atom of momentum to represent one of two directions. Pairs of opposing momentum atoms are created by force atoms. D During a particle decay, all of the momentum atoms in the particle are distributed into the decay products. Thus all such events conserve momentum.

Angular Momentum

Every bit has angular momentum. The reason has to do with the RUCA rule. The bits are conserved and the nature of the process is that angular momentum is conserved. This is a conservation law at the absolute most primitive level of DM. There is an important consequence of the exact conservation of angular momentum. In normal physics, it is well known that there is a relationship between angular isotropy and conservation of angular momentum. This is always looked at from only one direction. The assumption is that because normal physics assumes angular isotropy as a highest level principal, one can deduce from that highest level principal, as a direct consequence of angular isotropy, the law of conservation of angular momentum. DM turns this argument on its head. The most basic aspect of DM is the Bit, which has the dimensions of angular momentum. The Bit is absolutely conserved. This is a very simple consequence of the fact that there are only 2 states, +1 and –1 (in the Imaginary array they are +i and –i). There is no operation that creates or destroys bits. The only kind of change is that two adjacent bits can swap places. Thus, it is clear that bits are conserved and as an absolute consequence, angular momentum is conserved. Of course, conservation of momentum requires that the RUCA rule be chosen so as to enforce the conservation of angular momentum.

DM has at the bottom, the conservation of Angular Momentum. The net result is that as a consequence, there is asymptotic angular isotropy. The microscopic world of the RUCA is clearly anisotropic. However, the conservation of angular momentum enforces the macroscopic world of DM to pass macroscopic tests of angular isotropy – with flying colors. There is a very similar situation with regard to conservation of linear momentum in DM and the consequent asymptotic disappearance of the reference frame.

Unknowable Determinism

'Tis all a Chequer-board of Nights and Days

Where Destiny with Men for Pieces plays:

Hither and thither moves, and mates, and slays,

And one by one back in the Closet lays.

Omar Khayyám (1050?–1122), Persian mathematician, astronomer, and author.

English translation by Edward FitzGerald

The Rubáiyát of Omar Khayyám (1859).[27]

The DM Feynman Diagrams

The Nature of the DM Rule

No Spreading of the Wave

The fact that a wave is actually a collection of momentum and energy atoms, each of which are conserved, means that momentum and energy are conserved exactly

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Uncertainty Principal

When we look at some region of space-time we observe the following relationships. At a single instant in time, there is no way to measure energy. The concept of energy makes no sense for a single instant of time. Energy is a temporal wave. Since time is one-dimensional, energy is a scalar. It has no directional quality. Given 2 adjacent points in time, the value of the energy at a point in space (a single cell) must be either zero or E; either the minimum or the maximum. There is just 1 bit of energy information. The more time we take, the more the possible values the energy that a single cell can have. Obviously, there is a linear relationship between time and energy. In 10 units of time, there could be k units of energy, 0ιβk<10 per cell. The unit of time is T and the unit of energy is B/T, therefore the product Tx(B/T)=B. B is the Bit and it is approximately equal to h, Planck's Constant. What is normally called "The Uncertainty Principle" might be better known as the "Certainty Principle", since in DM it tells us the degree of certainty as opposed to uncertainty.

For momentum and spatial locality we have a similar situation. Again, looking at a single point in space, there is no way to measure momentum. The concept of momentum makes no sense at a single point in space. Momentum is a spatial wave. Since space is 3 dimensional, momentum is a vector. It has a directional quality. Given 2 adjacent points in space, the value of the momentum is

Force

DM models can easily deal with both a field model of force, or a particle model of force. We will describe both. It is also possible to have a model that combines both depending on circumstances. In DM Force=$BL^{-1}T^{-1}$. This can be interpreted (as done by Newton) as the rate of change of momentum BL^{-1}/T, or in various other ways such as as energy per unit length BT^{-1}/L or as the Momentum Energy product per Bit: $(BT^{-1}\ BL^{-1})/B$. Of course, in DM we have an atom of Force. Two bits that are neighbors, offset in both space and time, constitute an atom of Force. Force is involved in the creation and destruction of atoms of momentum. Momentum atoms are always created and destroyed in opposing pairs.

B

In DM, Energy is modeled as the frequency of temporal bit oscillations. The RUCA substrate may be thought of as a kind of Digital ether. Fields and waves propagate through the RUCA space in a fashion similar to concepts as to how such fields propagate through the space of a physics that has continuity. We expect that the gravitational effects of a very distant mass will grow ever smaller as the distance grows larger in both systems. However there is one very big difference between continuous and discrete models. If we look at the field model in physics with continuity, we know that no matter how much the effect is diminished by distance, there is always a smaller number to represent the strength of the field. In addition, we can assume that continuity leads to perfect superposition. If there are multiple distant masses, there is no problem with the idea of all of them contributing perfectly to the total gravitational effect felt at great distances. Perfect reversibility in ordinary physics is made possible by the fact that there is continuity and superposition.

In DM we have some similarities and some differences. The governing principles are reversibility and the total digitization of all quantities. This means that whatever represents a field cannot indefinitely decrease smoothly. At some point, the very weak field means that a quantized action takes place only occasionally. In DM, perfect superposition is a macroscopic result of a process that does not have perfect superposition at the smallest scale. If two distant identical masses each ought to cause the same particular 2 bits to swap then it is obvious that it will not be possible for there to be twice the energy that would have been there if only 1 distant mass had been there.

The process can be better understood by considering integer arithmetic modulo some base. Let us imagine 2 identical digital processes that only uses addition, subtraction, and multiplication. The computational process that both will follow will be identical, and the initial conditions will also be identical. The only difference is that process A uses arbitrary precision integers and process B uses arithmetic modulo N. Further, let us imagine that N is larger than 99% of the values that variables might take. The result will be that all the corresponding variables in the 2 processes will always have values that are equal Modulo N. In the long run, 99% of the values of the variables will be identical (because they are less than N). The results of the process computed modulo N will never drift away from the results of the process computed with arbitrary precision.

In DM, the extreme quantization must result in situations where the instantaneous value of a variable is incorrect, yet the long range consequences can come out exactly correct. This is what we believe happens in the case of what we are calling "*energy radiation*". Wherever there is Mass, it is basically a concentration of energy atoms, BT^{-1}. The necessarily accompanying momentum atoms are so arranged that most of them cancel each other out. This is possible since the momentum atoms are all vector quantities. Two momentum atoms whose vectors point in opposite directions have zero net momentum. This is the basis of mass; energy without momentum. The oscillations of the energy atoms excite the further oscillations in the medium, which spread out as energy waves. They do not carry much energy themselves. If there is phase coherence in the wave then it represents an electrical field. If there is oscillating coherence, then we have Electro-Magnetic fields. If it is incoherent or otherwise balanced, then the net result can be an energy field carrying no electrical field.

What we care about is the fact that all energy radiates, including the energy that represents the state of the field! While it introduces no long term error, the superposition of 2 energy atoms cannot instantaneously create in one place an energy atom with twice the energy. There is, in essence a kind of energy atom exclusion principle. The consequence is that space in the neighborhood of various masses does not have quite the energy density that it should. This effect is very similar to the example given of limited arithmetic modulo N where N is a small integer. The effect is proper in the long run, but in the short run, the total energy is less than the sum of the 2 energy fields. This spatial energy shortfall follows a function of m_1m_2/r.

What this means, given 2 masses gravitationally attracted to each other, is that the interaction of their energy fields has a shortfall due to the unusual superposition properties of the DM RUCA. The net result is that the total energy of the system of 2 masses is decreased by an amount proportional to 1/r, where r is the distance between them. This can be thought of as though a mass has an effect on space. A second mass would also have an effect on space however the result of the superposition of the two effects is that the net is less than the sum. Nevertheless, long term everything is still conserved. This is because the further propagations of the waves proceed identically with what would have happened if there had been perfect superposition. The consequence of the superposition deficit is the approximate inverse square law.

Simple discrete models

Emergent properties and behavior

Matching more and more of physics

Universality gives encouragement

The basis for eliminating constants

The basis for exact understanding

Progress is possible

The Cosmogonical Problem

Our Physics has Conservation Laws

***There is evidence for a* Beginning**

Conserved things seem to be here

If all there is is our Laws of Physics

Something is amiss

DM pushes the problem back to a* place *where there is no necessity for the problem to exist

DNeeding magic just once

Computation does not need 3+1D space

Does not need the Laws of Physics

Does not need or energy

Does not need time (as we know it)

Does not need particles or fields

An* engine *can be in a place where the cosmogonical problem does not exist.

If so, all needs for magic are gone; except for just one bit of magic!

What Have We Shown?

Feynman and Chequer Board

Marv Minsky and I both met Feynman one evening in 1962. We had accompanied John McCarthy on his visit to Caltech where he was considering the possibility of joining the faculty. That evening, Marv and I had nothing to do so we decided to visit someone. I suggested Linus Pauling, whom I knew as a student in the 1950's but he wasn't at home. Marv suggested Feynman, whom neither of us had met but both of us had heard of him. Marv called and Feynman answered the phone. He invited us to come to his house that evening. It was a magic event; we stayed into the wee hours of the night talking about many things. When we left, Marv said, "What a fantastic evening, we have to do this kind of thing over and over again, where we just call someone really interesting and drop in and visit them. I agreed and we both vowed to repeat that process over and over again in the years to come. To my knowledge neither of us has ever done so!

However, from that point on I never stopped visiting with Feynman and talking to him on the phone. We became really close friends. I had business reasons to often be in LA, but most of the times I went to LA, I stayed at Feynman's house in Altadena. One of the first things I did was to tell him about my interest in DM. I describe cellular automata as a kind of checker board, with simple rules. He was polite and listened, but had no real reaction. He had me spell "cellular automata", then he mispronounced it "cellular automata" where the "auto" was pronounced like the "auto" in "automobile" and the "mat" was pronounced like the "mat" in "doormat". He persisted in doing so for years!

From that point on, whenever we got together, I always filled him in on the latest state of my progress in the field I now call DM. Feynman always listened, asked questions and made comments. He always helped me whenever I needed to understand some aspect of physics as part of my work. Early on, Feynman politely asked me to never suggest to anyone that he had any interest in DM, or that he "approved" of my ideas. Nevertheless, he always listened and gave me whatever help in physics I asked for. Of course, Feynman had lots of complaints about how I went about trying to advance the state of DM, but he never made any suggestions other than telling me to drop all the other things I was trying to do and just make DM do Quantum Mechanics. But I never agreed and anyway, Feynman couldn't give me a clue as to how to do it. In any case, at his suggestion, we worked out a way that I could learn what he felt I should know about QM. The result was that I spent a year (1974-1975) at Caltech and during that year, with Feynman's steady help, I learned everything that he felt I needed to know.

One day, in the Spring of 1975, Feynman and I were having one more of our usual arguments about my DM ideas. But this time I somehow broke through with the logic of the whole concept, Feynman stopped and became pensive.

I waited to see where this would lead. Suddenly Feynman was angry, but this time not angry with me. “Dammit” he said, “I know that somewhere I once said something about it all being like a Cellular Automata, but I don’t know where and I’ll never find it.”

My thought was “Wow! Feynman not only is coming around, but he’s worried about wanting history to credit him for the ideas that I told him about.” Strangely, the idea that Feynman was annoyed that maybe he might miss out on getting credit for expounding the idea of DM simply struck me as an enormous complement. After all, my ideas must really have some potential if Feynman is angry because he thinks he might have thought them up but won’t get the credit for them. I was elated and happy, it was the very first direct sign from Feynman to me that he thought my ideas might have some merit in Feynman’s view. Of course, I always had the left handed compliment virtue of the fact that he was always glad to see me or hear from me on the phone, always kept talking to me, arguing with me and helping me.

I leapt up from my chair and stepped over to Feynman’s book shelf. I grabbed the book and a minute I found the passage he was thinking about in “The Character of Physical Law” which was based on the Messenger Lectures that Feynman gave at Cornell in November, 1964, more than 2 years after I started explaining my concept of DM to him.

“So I have often made the hypothesis that ultimately physics will not require a mathematical statement, that in the end the machinery will be revealed, and the laws will turn out to be simple, like the chequer board with all its apparent complexities.”

Feynman was grateful and triumphant.

I didn’t dare point out to Feynman that the lecture he gave was long after I started haranguing him about DM. All I wanted was for whatever it took to keep him motivated. This is a bit similar to the situation that developed at MIT after I had invented the Billiard Ball model of computation. The BBM was in response to an informal campaign at MIT to discredit my work on reversible computation. At that time, an important MIT Professor came up with an argument that purported to show that the Conservative Logic gate (known as the Fredkin Gate) could not have a physical implementation because it violated the 2^{nd} law of thermodynamics. While I felt that the argument was spurious, it was hard to refute directly without getting those who agreed with him to take my one semester course on Digital Physics. In order to cleanly refute that hypothesis, I was motivated to find the simplest possible model, within classical mechanics, that was consistent with Conservative Logic. Thus I invented the BBM. It solved my problem. Feynman always referred to them as “Fredkin’s Balls”, with a scatological glint in his eye. As my group started to develop BBM computational circuits, one of my students, Andy Ressler came up with a particularly attractive form of BBM gate I called “the selector gate”. At some point I explained the basic idea of the BBM to Feynman over the phone. I had long ago learned that

Feynman absolutely hated being told any interesting result that he might be able to work out for himself. So I was always very careful to not tell him too much. In fact it was always amazing how little he needed to be told; Feynman was particularly proud of that fact. He once gave me a puzzle "Prove the Pythagorean Theorem using construction; the right triangle with just one extra line." I struggled for a few minutes and came up with an informal proof. Feynman bragged how Fermi had given him the same puzzle back in Los Alamos days, and how he had the answer before Fermi had finished giving him the problem.

A couple of weeks after I told Feynman about the BBM, I got a letter with various circuits worked out. Among them was Ressler's selector gate. I and my students were always thrilled at Feynman's interest in our work, especially as absolutely no one in physics at MIT or Harvard gave a damn. We had a little meeting and all decided, Andy Ressler concurring, that the selector gate would henceforth be known simply as the Feynman Gate; part of our campaign to keep him motivated. Both Feynman and Ressler thought it up independently, so since Feynman's death, I've been referring to it as the "Feynman-Ressler Gate".

Rolf Landauer and I organized a meeting held in May, 1981 at MIT's Endicott House. Richard Feynman was invited by the author to be the keynote speaker. Feynman took his role as keynote speaker seriously, so he asked me the name of the conference. I told him that I hadn't decided yet, but that I was thinking of something like Computational Models of Physics. Feynman's response was that if the name of the conference implied something like my theories, namely something about computational models of physics, then he wasn't going to come. I told him not to worry, that I would change the name of the conference to some innocuous thing that didn't imply his association with my ideas. He said "OK, I'll come."

While I never told anyone about Feynman's admonition to me to never imply that he believed in any of my theories, I was nevertheless amused by his continuing concern. Michael Dertouzos, who succeeded me as the Director of MIT's Laboratory for Computer Science, requested the opportunity to open the conference with a few remarks. This was an appropriate suggestion so I met with Dertouzos to let him know what the conference was about. In the course of the conversation I had to explain why the name of the conference had been changed, so I simply told him that Feynman told me that unless it was changed, he wouldn't come. Now, you have to understand that the MIT establishment was hell bent on expressing its annoyance with me and my theories at every opportunity, and Dertouzos, knowing my notorious thick skin, decided to have a little fun with the change in name.

Michael Dertouzos opened the conference with a short preamble and then he couldn't resist tattling on me. He told the little story as to the fact that I had wanted to call the conference Computational Models of Physics, but that Feynman had told me that if that was the name of the conference, then he wasn't going to come. So Fredkin had to change the name of the conference. Ha, ha, ha.

Finally, Dertouzos introduced Feynman. Feynman got up to the podium and before starting his talk he commented on Dertouzos' introduction to the effect:

"Yes, it's true. When Fredkin told me that the name of the conference had to do with computational models of physics, I told him I wouldn't come. But since then I've changed my mind; my talk is going to be on Computational Models of Physics."

The actual title of the talk was "Simulating Physics with Computers".

Phillip Morrison, 1976

In the fall of 1974, I went to Caltech and spent a year there working with Richard Feynman. When I returned to MIT, in the fall 1975, I organized and taught a course called Digital physics for a number of years. When while at Caltech I hadn't discovered a number of very interesting things. When while I might have kept all this progress to myself and worked out the details and consequences of what I discovered at Caltech, instead I chose to present what I had done to the students in my course and to tell them about all the new developments that could follow. In essence I gave students homework problems where, when they solved them, they were solving problems that had not been solved by anyone up to that point. There were some brilliant students in my course, and in particular I remember Guy Steel very well, and many of these problems were solved by my students. Of course, but I was presenting was not the normal kinds of things that one would learned MIT. In addition to be breaking new ground in computer science we were talking about you ways of looking at physics. So the students in my course wondered about how much sense all this made. A little group of students went to visit to Phillip Morrison one of the most respected and famous physicists at MIT. They described the nature of my course and the fact that I was interested in Digital mechanics to Phillip Morrison to get his reaction. He made the following comments to my students "Ed Fredkin is a computer person therefore he believes that the universe is actually a computer. If Fredkin was a cheese merchant he might be telling you that the universe is made up out of cheese. What I found most amusing was that those students came back to me and told me this story.

An Apology

The purpose of this paper is to introduce the reader to a new way of thinking about our world. This is not a formal or mathematical treatise but rather a collection of concepts unified by the Digital Perspective. The author knows that this paper is full of errors but hopes the reader will be tolerant. There are two kinds of errors: the first, is where a concept being presented is basically correct but various aspects of it are erroneous, and the second is where the concept being presented is dead wrong. However the space of concepts is so very large that the author purposefully felt committed to thinking at the highest level and more or less ignored the normal standards of scientific research in order to move the entire concept forwards. Not to worry, all we claim is; something like the totality of what DM is or could be might be the way our world works. We apologize for not having been able to spend enough time to get everything right or even self consistent (not to say we have the ability to have done so). On the other hand, there is no doubt that during the half century wherein the author, to his knowledge, has had exclusive rights to work in the field of DM, it has never failed to make progress. Perhaps all that does is demonstrate how bad DM used to be.

Definitions

Computer: An entity with a memory and a processor. A computer uses algorithms that allow some of the information in the memory to control how any information in the memory is to be changed. We assume that parts of the memory may be shared with other computers.

Universal Computer: A computer that is able to run a program that can exactly emulate the information processing behavior of any other computer that has slightly less memory. This property is true of almost all commercially available computers. A very few computer designs, such as those in very simple digital watches, may not be Universal Computers.

Informational Process and Informational Construct: The state or memory of a computer is a set of Informational Constructs and what the computer does with them is an Informational Process. A computer looks at information represented in its memory and uses algorithms to change some of that information. While all of the information might be in the form of bits, there are groupings of those bits, or interpretations of them that constitute entities to be processed together. Consider a 64-bit floating-point number representing, in a computer memory, the mass of an airplane. That 64-bit number is an Informational Construct. Consider a block of 100 64-bit words that represent all the different dynamic parameters of the airplane; that block is also an Informational Construct. All Informational Constructs are involved in a digital informational process where either they evolve or they are involved in how other Informational Constructs evolve. We can say that the computer embodies an Informational Process that causes the evolution of Informational Constructs.

DM Space Index: This is the sum of the integer spatial coordinates of a cell in DM space.

DM Space-Time Index: This is the sum of the integer space-time coordinates of a cell in DM

P_n or Parity mod n is a DM parity taken modulo n.

Neighbors and Neighborhoods. The DM array contains a number of cells, each with 4 integer coordinates, x, y, z, t. At any instant, exactly 2 adjacent time states are simultaneously present. Neighborhoods are groups of cells, all of whom are present at the same instant. Normally all neighborhoods are characterized by containting a configuration of cells that are either adjacent or nearly adjacent to each other (spatially and or temporally).

Spatial Neighbors: 2 Cells whose space indices differ by ±2. Each cell has 12 spatial neighbors. These are all the nearest neighbors with the same time index.

Temporal Neighbors: 2 Cells whose space-time indices differ by ±1. Each cell has 6 temporal neighbors. These neighbors are closer spatially then the spatial neighbors, but do not exist at the same point in time. Rather, they exist at adjacent points in time. 2 cells at exactly the same

Word: A standardized set of letters, symbols or bits that is an Informational Construct available to some Informational Process. A word is often a pointer to other informational constructs or to a class of informational constructs. In most computers, there are words of definite lengths, e.g. 64-bit words, 32-bit words, etc. In a language such as English, words (that are not quoted) are symbols that represent informational constructs. Each word is an Informational Construct and a word that is quoted is an informational construct that points to or that represents the informational construct in the quotes. A horse is an animal while a “horse” is a 5 letter word starting with the letter “h”.

Computer Word: The memory of a computer is usually organized as a list of words. Each word normally has a given length such as 64-bit words. Thus each word in a computer memory can be thought of as an integer. In fact, the entire contents of the memory of a computer can also be thought of as a single integer. E.g. for a 20GB memory, it is an integer with about 50 billion digits.

Purpose: Purpose is a property of an algorithm and a set of informational constructs. The algorithm, with a computer as the engine, examines some informational constructs and on that basis changes some informational constructs. An algorithm has a purpose. It accomplishes its purpose by being executed by a computer. Some algorithms access no data outside the algorithm (They have no inputs) nor do they affect any data outside the algorithm (they have no outputs). An example is an algorithm that is designed to do nothing more that to use a set amount of the processor’s time. Some algorithms generate outputs but have no inputs e. g. a random number generator. Some algorithms have inputs but almost no outputs. E.g. a error detection program that always looks for certain kinds of errors but most likely never finds any. Normal algorithms typically have both inputs and outputs. They look at input data and it affects what the program does. The purpose of a computer is to act as the engine, to cause the time evolution of its memory in accordance with the informational constructs in the memory, some of which may be the algorithms.

In DM, there is an algorithm that determines simultaneously for the whole array, what happens within every very small neighborhood.

Richard Feynman

I had arranged a wonderful meeting that took place in Santa Monica at the Systems Development Corporation in 1962. After the meeting Marvin Minsky and I went with John McCarthy over to Caltech where John, not sufficiently appreciated at MIT, was looking for a faculty position. The powers at Caltech were not able to understand why they should make a good offer to John, so they didn’t. John ended up going to Stanford where he continues his illustrious career.

So, later that evening, Marv and I were still at Caltech and had nothing to do. Marv made the wonderful suggestion that we just call someone up and go visit them. I volunteered Linus Pauling's name, as I had known him when I was a student at Caltech. He wasn't home. So Marv suggested Richard Feynman. We called and were invited over. Thus began the most wonderful friendship and intellectual relationship of my life.

The next time Feynman and I met, not long after that first meeting, I was able to explain the then current state of my ideas about DM. In fact, everytime we got together, that was what I wanted to talk about. Feynman was always helpful, always listened, called me crazy but paid attention. As our relationship grew closer, Feynman made me swear to the following pact: he would listen to my far out ideas, help me with any questions I had about physics, but I was never, never to say anything to anyone that implied that he had any belief whatsoever in my general concepts (Digital Mechanics). He would teach me about QM and I would teach him about computation. He always helped me with my work and I always upheld my part of the bargain; I never say anything to anyone that implied that he had any belief whatsoever in any of my theories. That done, he always did his best to answer my questions about physics. He listened to me when I wanted to explain my ideas. He critiqued them in an honest and dispassionate way. We had a number of *far out beliefs* in common, namely that QM wasn't the final answer.

In 1974, I mentioned to Richard that I was thinking about taking a sabbatical, as I was tired of being the Director of MIT's Laboratory for Computer Science. Richard invited me to spend the year at Caltech as a Fairchild Distinguished Scholar. This was a new program that gave rather lavish support to a few visitors at Caltech. Stephen Hawking had already accepted and was going to be at Caltech that same year. I agreed, and we made plans to work together. While my office was just down the hall and around the corner from Richard's office, we always met in his office. We spent a lot of time together talking about my stuff, about computers or about physics. We never talked about Feynman's current interests in physics, as I wouldn't have understood. We always talked about the physics in the Feynman Lectures, about computation and about my theories.

I had decided to tackle a particular problem while at Caltech; it was to come up with a convincing model of reversible computation. This was to be a leap over the most significant hurdle on the path to my more general theories. In trying to teach Richard about computers, I had my best success with Cellular Automata. Of course Richard knew that I wanted him to think about Cellular Automata as a potential model for physics and he didn't want to. "Automata" is pronounced a lot like "autonomous", but no matter how many times I used the word, Richard always said "auto mata" with the "auto" pronounced as in "automobile". I never could tell if this was just a Feynman eccentricity or an attempt to get my goat (which he often tried to do in more obvious ways). As time went on, and Richard and I greatly enlarged the body of physics and computation knowledge we shared in common, he started to come around. He often reminded me that I was never to suggest to anyone that he believed in my theories, but he did begin to understand and appreciate what I was trying to do. In any case, a good proportion of our discussions involved Richard screaming at me, telling me to just think about Quantum Mechanics and to ignore everything else.

One day when I was trying for the n^{th} time to get Richard to understand why a Cellular Automaton was an interesting model for discrete physics, I finally got through to him. He suddenly became very serious and pensive. It was a tremendous moment for me because it was now a good dozen years since I started trying to get him to understand my point of view. Up until then he had always listened, asked questions only to understand what I was getting at, tried to understand what I was thinking, and then always pointed out that my ideas were off the wall. What happened next just blew me away. To understand the significance of what happened you need t know a little more about Richard Feynman.

Richard took serious ownership of his best ideas. He wanted people to know how smart he was. Here's one anecdote. I had a friend who, as a sideline, owned a company that did van conversions. This meant that they would buy Ford, Chevie or Chrysler vans, and customize them for customers with special seats, fancy stereos, paint jobs and other goodies. At one point, Richard told me that he needed to buy a van, especially for making trips down to his house in Baja California, (Mexico). I suggested that my friend could customize one for him.

Richard asked, "So, what does he do?"

"You can get fancy seats or any kind of paint job you want."

"What do you mean '…any kind of paint job…'?"

"It's not just painting it any color, they do pictures, murals, anything…"

And at that moment, with a model of Richard's ego and with knowledge of his vanity license plate which was "PHOTON" firmly in my mind, I continued

"…you could even have Feynman Diagrams painted all over the van."

Richard grabbed a piece of paper and a pen and started drawing Feynman Diagrams.

"You mean that if I just draw a bunch of diagrams like this, that your friend could do a decent job of painting them on the van?"

"Absolutely!"

That is what Richard got, a whitish, nondescript van, with a large collection of Feynman Diagrams painted all over it.

One day he and I went to a mall in his new van. As we were walking back to the van, we saw someone standing near it staring at the diagrams. Richard quickly got into the drivers seat and put his window down, kind of inviting the young man to ask a question or make a comment. He bit, and asked Richard, "Why all the Feynman Diagrams?" Richard started the engine, turned to the young man and said, "Because I'm Richard Feynman!" and off he drove.

Back to Richard's office. Richard was standing and I was sitting, a common combination. I was full of emotion, wondering if Richard was finally going to tell me that there was something important about Cellular Automata and physics, the concept I had been hassling him about for the prior decade. He was just standing there thinking and it was clear that something was bothering him. I started to get depressed. "Well, after all, maybe he's trying to wriggle out of it and find yet another reason to put me down." I thought. I knew that Richard had thus far never said anything that would credit me and my theories with being something important in physics, even though I thought that I was slowly winning him over.

Then, Richard quietly said something that struck me like a thunderbolt out of the blue. What he said was, from Richard Feynman, the greatest possible validation of what I had been trying to get him to understand over and over since I had first met him. What Richard said, with annoyance and a little bit of anger in his voice was: "You know, I'm sure I've already thought about the idea that some kind of Cellular Automata is probably the fundamental process in physics…" which I had been trying to convince him for more than a decade. He continued; "… and I know I said something about it somewhere…"

Richard Feynman was claiming priority for my idea, which I had been pestering him about for 12 years!!! What greater endorsement was possible? Nothing. Nothing at all. For me, this was it. I knew exactly what Feynman was thinking of. It was a casual little comment he made during one of the 7 lectures Feynman gave at Cornell (the Messinger Lectures), which was transcribed and published in a little book called "The Character of Physical Law". I leapt up and went to his bookshelf. I quickly found the book and in a few seconds found what Richard was thinking of on pages 57-58.

"It always bothers me that, according to the laws as we understand them today, it takes a computing machine an infinite number of logical operations to figure out what goes on in no matter how tiny a region of space, and no matter how tiny a region of time. How can all that be going on in that tiny space? Why should it take an infinite amount of logic to figure out what one tiny piece of space/time is going to do? So I have often made the hypotheses that ultimately physics will not require a mathematical statement, that in the end the machinery will be revealed, and the laws will turn out to be simple, like the chequer board with all its apparent complexities."

Richard was beaming. He thanked me for finding it. He was so happy. And so was I. This was the first time that he directly expressed to me support for my views and I was in no way bothered by either of two interesting facts: first that his support for my ideas was indicated by his feeling that he thought up the germ of those ideas (as he indicated in his book), and second, that he had forgotten that he got the germ of those ideas, as quoted above, from my trying to explain it to him over and over during the few years we knew each other before he gave the Messinger lectures at Cornell.

Perhaps I'm weird. Here is the essence of my work, which I started on in earnest in the late 50's, which I had explained over and over to Feynman, which he had ridiculed repeatedly but never refused to listen to me, and what is Feynman doing? Feynman doesn't want to be left out! He wants to remember that he had the ideas back when he gave the Messinger lectures. He doesn't seem to remember that I had pestered him about those ideas for years before he gave the Messinger Lectures, and I'm ecstatic. Why shouldn't I be? What better endorsement than having Feynman wanting credit for my ideas? However Feynman was not like me in that we both knew that espousing Digital Mechanics (as I eventually called the field) was a sure way to label yourself as a crackpot; something even Feynman was afraid of. He still continued to caution me that I must never suggest to anyone that he had any interest in such things.

Perhaps I was being a bit manipulative with Feynman, but his interaction with me was so very valuable to me that I put the continuance of that relationship above all else. This

When I first read "The Character of Physical Law" I realized immediately that there were a number of things in the book that were a consequence of his interactions with me. Most of them were criticisms of me and my way of thinking, disguised as general comments. I knew that because the identical criticisms were heaped on me directly by Feynman.

When I would call him up to tell him about a new concept, he usually would write me a note, a few days or weeks later, indicating that he had been working on it and had produced some interesting further developments. Just what I hoped my students might do! As time went on, I could see that his appreciation for what I was trying to do grew. He was tireless and indefatigable in his efforts to make sure that I truly understood the answer to a question I might bring up about physics, particularly in the area of quantum mechanics. We often argued fiercely and for hours. He would get very emotional if he thought I didn't have an exactly correct picture of some quantum mechanical process. What impressed me most of all was how much he cared. The more he yelled at me the happier I was because I wanted to get it right and I knew that Feynman wanted me to get it right.

Trying to teach Feynman about computation was even harder than his trying to teach me physics. The problem was that Feynman absolutely did not want anyone to tell him any really interesting ideas. He wanted to be give a few (but not too many) hints so that he could discover it for himself. His first reaction to his first use of a computer was like that. He wanted to discover how it worked as opposed to reading the manual or having me show him. Unfortunately, while that method worked well in many areas, it didn't work very well in the field of computers, especially back in the days when Feynman and I made our pact (in the spring of 1974).

It was a strange collaboration. And it was one of the 2 fruitful collaborations I have had. The other was in my mid-twenties with J. C. R. Licklider. From Lick, I learned how to do science. From Feynman, I learned that I could trust my intuition about physics and about quantum mechanics in particular. With my students and other research partners, it was strange. They did and good work and some are still doing good work. They learned from me and I learned from them. Some, such as Norman Margolus and Tomasso Toffoli did things that helped me. Yet I cannot say that there was ever any collaborative effort that benefited my work. Many times I went to an associate with the kind of question or need for help that led me to interact with Feynman, but aside from Feynman, I can't recall a single instance of where I framed a question or an area where I needed help, and where I got it. With Feynman, that was the rule; I would call him up and ask a question, he would sometimes give me the answer on the phone, he would sometimes think about it and get back to me weeks or months later. Sometimes he couldn't help me, but he always tried and he always made me feel like he really wanted to help me in every way he could.

In 1980, Joyce and I got married in a little church in Gun Creek, Virgin Gorda, British Virgin Islands. Richard and Gweneth Feynman, and their two kids, Michelle and XXX, came down about a week in advance. He was my best man at our wedding. Joyce and I had a disagreement as to whether or not I ought to wear a tie at the wedding. Ties are seldom worn by me and ties are seldom worn by anyone in Virgin Gorda. I don't know why I persisted in my plan to not wear a tie, I was just plain stubborn. Richard took me aside and with that peculiar Feynman passion, explained to me why I had to wear a tie. I got the message and I wore a tie.

Both Feynman and I had personalities and life styles that did not allow for often interactions. We occasionally talked on the phone, he wrote me letters, and we had visits. When he came to the Boston area, he often stayed at our house. When Joyce and I went to the LA area, we usually stayed at the Feynman house. In some sense I wished for a lot more interaction but my work was progressing too slowly. Luckily, we were never were around each other enough to get tired of each other.

When Feynman knew he was most likely dying, we had little interaction. His way of letting me know the seriousness of his last bout with cancer was to tell me that when he was gone, I might try talking with Sidney Coleman, a well known physicist at Harvard. I was pretty much overwhelmed to realize that facing death, Feynman was concerned about the loss to me of his continual willingness to try to answer my questions about physics.

Somehow I wanted to go and spend time with Feynman. He discouraged me and I found it easy to accept his view. Every so often I had the urge to drop whatever I was doing and rush out to California, but I had so many ambivalent feelings that inaction won out. This all caused me a great deal of pain.

Some time after Richard passed away, I was invited to be one of a few speakers at the Feynman memorial being organized at Caltech. I accepted. Joyce and I and Richard, then six years old, went to California. There was such a large turn out that they simply held the same memorial service twice; dividing up some of the speakers with others giving their talk twice. Richard Fredkin came to the second section. After it was over, after I and the other speakers came down from the podium, Richard came up to me and said to me, in a most serious manner:

"I was a friend of Richard Feynman's"

"Yes, that's true."

"How come I wasn't asked to speak?"

I went and introduced myself to Coleman. I tried to explain my ideas to him. With Feynman, he would yell at me, scream at me, call me names, explain with passion what he thought was wrong with my ideas. Coleman listened politely.

Richard Fredkin at the Feynman Memorial service at Caltech. Al Hibbs.

Bio – History

Licklider and I had a deal, I would teach him about computers and introduce BBN to computers, and he would teach me to do science. It was a wonderful collaboration except there were important computer ideas I could never get across to Lick, and there were aspects of being a scientist (such as publish, publish, publish) which Lick could never get me to do. He did, however, by dint of the most persistent pestering, get me to write up one piece of work I had done called (by Lick) Trie Memory. I became a full professor at MIT in 1968, but for many years after that Trie Memory was still my only publication.

At BBN, we got the very first computer that Digital Equipment Corp made. It came with no software whatsoever. I had to write the operating system, the first symbolic assembler and I designed the first compiler. I had to design the I-O system, invent the interrupt and the swapping drum memory system. In those days buying a computer was different. I designed the character set (ASCII hadn't been invented yet) and many other aspects of the computer. It was fast and it had a CRT display that could be made to display objects moving around. And as I used that machine, as the 1960s were beginning, I came to realize that I had found the answer to the big issue that had puzzled me since I was a child.

I am now going to tell you what it is. I really do want to share it with everybody. I know that that will happen someday but I would like to live to see it happen. It's been strange, because I have profited enormously from my incompetence at communicating a simple idea.

Imagine a world, with a great library, where no one can read. Assume someone discovers the idea of reading, teaches himself to read and starts to read the books in the library. Further, assume that this person tries his best to get others to learn to read, but is unsuccessful. The result is that he is a failure at communicating his discovery. However, he still has this great gift in that he can read more and more and learn more and more. In time he will know many things that no one else knows. In some sense he should treasure and guard his secret but it doesn't matter. No one else is interested in the library, regardless of what he tries to tell them. It's a bit lonely but that loneliness is nothing compared to the thrill of being able to understand and appreciate knowledge about the world.

Of course, there are reasons why no one is interested in my gift. Actually, there are just 2 reasons. The first reason is that most people have no interest in the general subject matter of my gift. They are, to a greater or lesser degree, interested in other things. The second reason is paradoxical. There are people whose consuming interest is exactly in the area of my gift. They want to know how the world works. My gift has been letting me discover how the world works. They are scientists, physicists, philosophers. I am a scientist, a physicist and a philosopher. But nevertheless my gift has remained and still remains exclusively mine. Its partly because I won't speak their language and no one else has been able to learn my language. I have played a silly game where I have evidently tried to communicate to the scientific community in my language. While it is easy to understand, no one makes the effort because only *crackpots* refuse to talk to physicists in their language (as published in Phys Review Letters, etc.).

For the longest time this was a puzzle but I didn't care. However I wondered about it. I now have the answer. My behavior can only be described as selfish. And that is true despite my impression of myself as generous. But the results speak for themselves. Here it is 50 years later and I have, the whole time, been the only one in the world able to see what everyone will be startled to learn sometime in the future. I can't complain.

When I was at MIT I tried to give little yet wonderful gifts to my students. When an ordinary student studies geometry and is asked to solve a problem for homework, he knows that it's an exercise; someone else solved that problem thousands of years ago. When I would discover something new, something that up till then no one on Earth had ever thought of, I would realize that by keeping it to myself, by working it out myself, I would discover other related things. But instead of doing that, I would give the raw nascent discovery to my students and let them work it out. I know that I gave my students homework problems where they were doing original research. I thought that the thrill of finding a solution or an answer would turn them on to become interested in my field. But, aside from a very few exceptions, it didn't work.

My methods are not typical of science. Nearly everyone who makes a discovery and realizes that he is on to something hot, keeps it under his hat until he can secure credit for his discovery. He wants the credit. History is replete with stories and anecdotes about the lengths gone to by famous scientists to assure themselves of credit for as many discoveries as possible. Yet despite my strange ways, or maybe because of them, I go on as the only one who sees the big picture.

The thrill of understanding what little I do about the most fundamental things in our world has been more than enough for me. I wake up in the middle of the night, realize that I know yet another fact about how the world works, revel in the glory of my gift, and then I go back to sleep. I never have to worry about hurrying or publishing first. It doesn't seem to matter because for whatever reasons, this field of research is mine, has been mine since it started and will probably still be mine alone for some time.

Of course, there are others who share some thoughts and concepts similar to mine, but there really is a difference. My gift has given me a consistent global vision of the most basic explanation for everything. It addresses every fundamental question. The plausibility of my view is totally convincing to me. The absolute impossibility of the contemporary view of the scientific establishment on similar questions is crystal clear to me. While there are some who buy into a few snippets and concepts of my global vision, everyone (every sane person) but me would be loath to admit to what I insist is true. A small number of scientists and philosophers have put forward fragments of the vision I have, but they do it in a way different from me. Those who might follow my path have to understand the stigma that will follow them. They will be branded as a crackpot and their ideas will be dismissed by those who neither understand them nor even try to understand them. This could be terrible punishment for most. They might have difficulty getting a position where their work would be supported. They would find that most scientists simply won't pay any attention to what they have to say.

But I am lucky. I don't care and never have. I don't need anything. I don't need any big and expensive experimental devices. I don't need the support of a great institution. I might like a colleague, but the risk to anyone good enough to help me is normally too great.

For a while, I did have someone who was willing to help me in this endeavor and he did. That was Richard Feynman.

Notes

It is the place **B**s exist and where the various patterns of the **B**s represent the various particles, fields and in general all things of physics.

It is the engine that powers the digital informational process that drives physics.

Change occurs when neighboring **B**s in the *present time state* swap places, as determined by patterns of **B**s in the same spatial neighborhood but from the *past time state.*

Some configurations in a present B neighborhood cause 2 B's in the prior state to swap places.

DM Space-time is chiral; implying CPT

Note to EF …. look at the space-time parity mod 6 (or other similar ways to define a larger neighborhood!!!!)

The Big Question

The laws of physics are reversible. That means that there is no possibility of intervention within the laws of physics that changes the evolution of the system. What all this tells us is that there is a purpose to the Universe. We can know that there is no way to determine the microscopic future other than allowing things to run their course. This is a consequence of the speed up theorem.

Can we ever figure out what the Big Question (BQ) is? I think that the answer is "We can make some very good intelligent guesses, and perhaps even figure it out."

First, we can answer in the negative many candidates for the BQ on the grounds that there is no need to run the Universe for billions of years of our time to get to the answers.

The BQ cannot be about what kind of matter will exist; cannot be about whether galaxies will evolve, cannot be about stars. It cannot be about chemistry, about anything to do with the laws of physics, etc. We arrive at all of these conclusions simply by assuming that the framers of the BQ, who went through the trouble of running this big DM system, are unlikely to be stupid. We must assume that there is a reasonable match between the space-time volume of our universe and the difficulty of obtaining the answer to the BQ.

Could the BQ be about life? Could it be about whether or not life (as we know it) would evolve given the rule and initial conditions? We think not. Again, the problem seems too small to warrant this Universe. Slightly different rules could have allowed the simultaneous existence of trillions of Earth like planets circling hospitable stars; all in a tiny fraction of the volume of the current Universe.

Perhaps it's about whether or not an extreme form of Bose condensation could occur in a Universe like ours. The way that might work is explained in a story about a complicated dream that occurred to the author[28]

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[i] Ed Fredkin

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[28] The dream has been documented under the title "XXXXXX"