ON THE ORIGIN OF SPACE

A CENTURIES-OLD THREAD OF HYPOTHESES (AND SOME OF ITS MODERN CONSEQUENCES FOR PARTICLE PHYSICS AND ASTROPHYSICS)

ABSTRACT

This exploratory study reviews works by Everett, Feynman and others dealing with the nature of the quantum in light of hypotheses by Bruno, Leibniz and Einstein about the origin of space. A common thread is identified within this centuries-old line of thought, leading to an alternate conceptual approach for the problem of the elements making up our reality. By departing entirely from classical concepts the approach appears to allow bridging the gap between the sets of principles forming Einstein's Relativity and Quantum theories by logically pointing toward a space/matter continuity equation and various quanta-generated space manifold structures. Unlike Everett's original "relative-state" formulation of quantum processes, this extended formulation may be supported by experimentally verifiable consequences. In that respect the review addresses (1) Particle Physics, where a Higgs field is found not to exist as a direct consequence of the hypotheses, in contrast with the present expectations of Quantum Field Theory, and (2) Astrophysics/Cosmology, where through existing supernovae surveys the formulation points in a direct way to redshifts as Hubble obtained but without postulating an overall expansion for the envisioned open universe. A number of formal principles and process descriptions from Quantum and Relativity theories such as wave-particle duality, wave function collapses, null-measurement, quantum state preparations, mass and energy as well as Mach's Principle are replaced with constructive physical descriptions. In order to cover composite quantum systems, and in particular extended computational processes, Everett's original work receives a needed clarification backed up through a Feynman's path integral analysis. However, a complete formalism suitable for addressing the hypothesized elements of reality cannot be provided within the confines of this review due to their intrinsic novelty for existing Mathematical Analysis. To develop the remaining formalism work is required (1) in the mathematics of the continuum and physical systems evolution (in general mathematics revising or rejecting the Axiom of Choice), (2) to identify the details of a cosmological continuity equation, and (3) to formalize the kind of computational processes identified here. Also, due to the limited aspect of the potential evidence available in the two addressed areas of Physics, a set of more substantial confirming consequences related to quanta-generated spatial structures will need to be identified elsewhere through a separate review.

Keywords: axiom of choice, composite quantum, computation, continuum, cosmological model, cosmology, decoherence, higgs field, many-worlds, monads, multiple-realities, quantum, quantum computation, redshift, relativity, spacetime, standard model (particle physics), undistinguishability, unseparability, wavefunction

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I. INTRODUCTION

This exploratory study grew out of a personal reference I have been maintaining over the years in order to make sense out of key gaps and inconsistencies in the approach presently followed by the Physical Sciences to identify the make-up of our reality. I go past the understanding found there, taking a hard look at the known facts and hypotheses with the goal to find at least an experimentally *verifiable minimal hint* at how to proceed out of the present difficulties. The various parts of this search are divided into two phases intended to be published separately, with the initial phase summarized below.

As Einstein and Bronowski pointed out,[1] knowledge is not enough to reach the true make-up of reality, and imagination must be brought in to tackle such a task. So, in order to set the initial direction of the search, Section II looks at some of the past and present themes of the *scientific imagination*, taking stock of where others went or have been going. In particular I find that the 19th century prepared the ground for the discovery of the atom by going from the principles of Thermodynamics to the constructive theory of Statistical Mechanics through the old vision of the Atomic Hypothesis. This matter was part of a few clouds on the horizon of Physics present at the end of the 19th century that ultimately ushered the key theories of the 20th. A scratch on the surface reveals a worse situation now. I then orient the search toward *preparing the ground* for replacing the two essentially separate sets of formal principles established in this century, namely Relativity and Quantum Mechanics, with one future *constructive* theory that would cover them both. Needless to say, such a theory would fill a major gap in our knowledge and clear the corresponding cloud now present in our understanding.

In order to get a start toward such an elusive goal, I have to go back again to History and try to distinguish the concepts that were missed earlier. Then, through the three next sections, I examine several hunches expressed by various scientific personalities from the past as well as from the present. I succeed in identifying a common thread in them by filling up the incomplete thoughts and entering the latest facts obtained from Nature that the original thinkers did not know about, and end up that way with hypothetical elements that would underlie the present formal theories. But the nature of these elements, as expected from their intrinsic novelty, appears to be foreign to the existing framework of Mathematical Analysis. Since I need to go past the conceptual level to detailed features in order to obtain experimentally verifiable consequences supporting the hypotheses, I have no choice but to forget using a formalism to guide the search and follow instead a purely physical approach remaining close to experimental data. To avoid falling into a sidetrack, quite likely through such an approach, I keep the analysis in check by ensuring that this data covers *several a priori unrelated* fields. I do find in the resulting evaluation that isolated analyses can have a formal treatment. They are then placed in appendices as “mini-papers” to serve as input along with the experimental data. Such papers cannot be fully evaluated by themselves, and thus be published separately, because they need an overall understanding that only a broad approach like the one followed in this study can provide.

This required analysis of past experiments, which initially involves Particle Physics, is extended through two other sections (VI and VII) to Astrophysics and Quantum Physics. I examine there consequences not only to corroborate but also to sharpen the picture obtained earlier. I end up addressing a second cloud in our understanding recently identified through experimental data over two key hypotheses underlying the Theory of Relativity. Notably, I find that the universal spatial expansion, thought to have been observed for now two generations, looks to be instead a physical effect *originated locally* through the make-up of space, itself a product of the elements of reality hypothesized earlier. A conclusion of that magnitude cannot be supported solely through Astronomy and a negative result in Particle Physics due to the possible alternate explanations inherent to the elusive effects being considered. I have then no choice but to contemplate once more widening the corroborating experimental base of the approach. This attempt is envisioned at this point to be carried out as a separate review in the Life Sciences, as a key hypothetical feature of reality identified in Section V looks to have its most immediate evidences in that field.

While the search had to start at a remote level in order to establish a key understanding extending our present physical principles, the ensuing evaluation ends up building *a falsifiable whole* with a number of predicted experimental consequences. Two a priori *unrelated* areas are found available for such a purpose: Particle Physics and Astrophysics. If the third field of Biophysics can be added, then even though each of the evidences will have its limitations, when considering them together they ought to be able to ultimately establish the validity of the formulation.

Due to the exploratory nature of this study, the text hints in several places at theoretical analyses that cannot be included. For example, there is some information provided to establish a formalism covering the hypothesized elements of reality and the kind of continuum they need. I include a rough summary of such potential analyses in a last appendix, mainly to outline the extent of the work that would need to be done in the eventuality the proposed hypotheses are found experimentally supported.

II. A SHORT HISTORICAL PERSPECTIVE

A. The long search for answers

The first known of long-lasting “best efforts” in the search for answers about the makeup of reality was a *system of ideas*, the ancient Greeks’ view of the world, a world imagined to be made out of four “elements,” earth, water, wind and fire. Why 4, and not 5, 6 or 3? Because it seemed obvious at the time.[2] These elements were seen as molded and directed by gods to follow not only their moods and passions, but also the eternal concepts of numbers and geometric figures. The goal was no less than to read *the mind of the gods*, so ways to understand and thus be able to control fate could be found. The result was Euclid’s “Elements,”[3] among several other mathematical starters that happened to remain unequaled for almost two thousand years.[4] Here then I have an example where the vision was containing some truth, and only time proved that fact. On the other hand, such a lapse of time without further progress demonstrated that reality needed more than imagination and mathematics in order to be understood.

With the Renaissance in Europe imagination was at last combined with *experimentation* by Galileo.[5] Why? Because as a bright young man he was revolted by the manifest fantasies he was being taught at school such as weights not falling at the same rate, which for him was an obvious falsehood that he proceeded to test.[6] A check on such fantasies was overdue, and the time allowed freedom of thought, or so he believed. In the meantime, Cavalieri's seat-of-the-pants "indivisibles" modeled on the old Archimedes geometric dreams were a preparation for the "calculus" of Newton and Leibniz, just in time for the astronomical data processing by the astrologer Kepler to provide fodder for the first wild guess at "fields," gravitation.[7] Yet Newton's output was all still conceived very much as a fantasy: how can cosmic bodies act on each other instantaneously at enormous distances? "Hypothesis non fingo," I will not form a hypothesis, mumbled Newton, and on that word left Science for managing England's Mint.

From the mathematical consequences of the mechanics surrounding the discovery about gravitation, Maupertuis, Euler, Leibniz and others later on such as Lagrange and Hamilton *mathematically distilled* the "Principle of Least Action," a principle that allowed the world to *imagine* a parsimonious god guiding the evolution of our reality for the best of everyone, at least as far as the mathematics could tell.[7] In a sense it was the "Theory of Everything" for three centuries. Imagination looked at this deduction from mathematics and prepared an immediate revenge. Voltaire derided the whole thing with the phrase "we are in the best of all possible worlds" put in the mouth of a friend of his famous Candide (Dugas, 1988). It was the "fields" born in the imagination of the experimenter Faraday followed by the "aether fluid" of Maxwell that *led* us to the electromagnetic field, not mathematics. Just in time for Einstein, through his imagined travels at the speed of light, to realize that this second field did not jazz with the first one by Newton, forcing him to at last tamper with the absolute space and time of the Greeks that Newton took for granted, thus putting himself in the position to imagine a curved "spacetime" to explain the origin of gravitation.[8] He only had to call on his friend, the mathematician Grossman, to make his vision "reasonable." This approach seemed at first glance to replace the action-at-a-distance intellectual void from Newton with a physical connection between cosmic bodies through the "curvature" of this new spacetime. At least the world thought so.

B. A few clouds on the horizon

But with the turn of our century, the epoch arrived, unlike Voltaire's time, to "seriously" question imagination in the name of scientific "purity." Science was a serious thing after all! A first philosopher, Ernst Mach, derided the 18th century Principle of Least Action as only a tool without any metaphysical or teleological meaning, with no deeper origin than the theories it explained, themselves based on experimentation.[9] Mach was much more effective than Voltaire at influencing scientists, being a scientist himself after all. Manifestly Einstein could not be taken seriously with his curved spacetime since the theory failed to explain *what is space made of*, as not only it can curve and flatten but *shrink and expand* too. An expansion or contraction can only happen to "something" physical after all. It looked like "hypothesis non fingo" all over again, but this time unstated.

For Mach[10] this state of affairs vindicated his philosophy, Relativity being only a *set of principles* with no intent to provide a *constructive* description of the true elements of space and time, only a *formalism* to describe gravitation. But Science would not reach its goal if such elements were unknowable as Mach implied, being understood then as *the work of a deity*, thus unreachable by Science. Further, the concept of curved spacetime may have been all right if its "spacelike slices" had a constant total volume. As a matter of fact a *static closed universe* was Einstein's original idea. He even introduced a "cosmological constant" to make it so in his equation before Hubble told him he was seeing an expansion of the cosmos through his telescope. Then the constant became the "worst mistake of his life." I think more likely that Einstein lost track of his original inspiration at that very moment. Not that the constant was right, but that his theory was missing something after all, and maybe not a constant, and he tried to find the missing elements for the rest of his life. I shall see in Section VI what can be made of this in light of recent astronomical data. In the meantime this problem will be the "first cloud of 20th century Science."

As a result of the discovery of the quantum between 1900 and 1930,[11] a second philosopher scientist, Niels Bohr, spread out the injunction against imagining further beyond experimental confirmations and predictions in physical theories, this to the profound dismay of Einstein and Schroedinger, who knew where their physical theories came from! *Metaphysics was not to influence the mind of physicists any more.*[12] "Imagination" a la Maupertuis and "visualization" a la Maxwell were no longer to be tools of discovery, only theories following closely results of experiments were to be taken seriously. Theories made of principles were to be conceived, not constructive descriptions of the true elements involved as they were supposedly unreachable by the Human mind. As an example the "liquid drop" model of the atomic nucleus served well in bringing the nuclear bomb to the world, but no-one, including its inventor Bohr, would take it as having any meaning for the constitution of matter, only as a tool to do calculations. An obtuse set of principles called *Quantum Physics* was born in that manner from the efforts of Planck, Einstein, DeBroglie, Bohr, Pauli, Heisenberg, Born, Schroedinger, Dirac, Fock, Landau, von Neumann[13] and many others to mathematically explain by means of principles the results of experiments at the atomic level. These experiments seemed to leave us no choice but to conclude that both matter and radiation have a *split personality*, both wave-like and particle-like, the origin of which we could not know. Nothing was to be presupposed further according to Bohr. His "Principle of Complementarity" (Bohr, 1928) was thereby elevated to a "Natural" principle, implying a "least action" role for imagination.

But imagination refused to shut down. A late 1950s paper (Everett, 1957) right after the death of Einstein by an imaginative graduate student named Everett showed that this split personality of matter and radiation may be in fact hiding a *multiple-reality* quality for the universe. I shall look at this fundamental hypothesis in Section III, as it appears to be one of the key concepts dreamed by Humanity, ranking with the Atomic Hypothesis, maybe even more important. This work was kept in the university files carefully away from the limelight until the 1970s when it was dug up in a desperate attempt *to reconcile Quantum Physics with the physics of* Einstein (DeWitt and Graham, 1973) as these two did not connect at all with each other. This last effort, even with the use of Everett's vision by Hawking[14] and others, has been in vain in spite of 50 years of arduous efforts by a plethora of scientists. Would this, maybe, come from the still remaining theoretical void on the ultimate nature of space and time in Einstein's theory as I discussed above? Or is it because the multiple-reality idea as the route to a constructive theory of the quantum is itself incomplete? Maybe both, as I have already outlined for Einstein's theory and shall see in Section III for Everett's view.

I shall call the absence of a "quantum gravity" theory and the related debate on the meaning of the quantum (the Multiple-Reality Interpretation vs. Bohr's Complementarity Principle) the "second cloud of 20th century Science." Unlike the previous cloud, this one was not born from experiments not matching theory, but from formal theories not connecting to each other. Roger Penrose stated (Penrose, 1994) that a new revolution in Science will be necessary to clear up this cloud. I think that we must get unstuck from the mathematical quagmire of present theories and attempt to go beyond them by identifying new constructive hypotheses, even if a formalism is not available or even possible to deal with them. Such a route was followed in the late part of the 19th century by Boltzmann and others when the Atomic Hypothesis of the Greeks was brought back into the forefront of Physics to explain the phenomena that Thermodynamics was unable to describe. As to the lack of formalism, Faraday earlier handled such a situation by sticking to experimental verification to prevent going into some sidetrack. Empirical and heuristic rules can lead the way. The essential is to find physical effects corresponding to the envisioned constructive hypotheses from which we can develop further our understanding.

C. The gathering storm

In the meantime, still in the 1950s, and in the spirit of Mach and Bohr, Yourgrau and Mandelstam (1955) attempted to deliver the final blow at the metaphysics behind the Principle of Least Action. Bad luck, as Feynman was right then demonstrating that Nature after all had a good reason for following such a principle because of the newly discovered quantum aspect of reality, and in particular the quantum "stationary phase trajectories" as they were mathematically required by Schroedinger's nonrelativistic equation for the electron. Feynman enthused by his discovery thanked Dirac (Mehra, 1994) for the original hint. But Dirac didn't want to be associated with his wild and imaginative guess, he wanted to remain an "austere" physicist. Subsequently, and without publication, Feynman tried to find a stationary phases origin for Dirac's own relativistic equation of electron motion by postulating that *everything at the fundamental level in this world goes at the speed of light* (Schweber, 1994). Needless to say that such a bizarre (but fundamental) idea also merits to be explored further, and I shall do so in Section IV.

But Feynman's unpublished hypothesis was not very consistent with someone who was intent on getting rid of metaphysics in Science as he wanted to portray himself, and so maybe, deep down an ambivalence crept through him, as he was undoubtedly influenced by Bohr and Mach. For example, in the 1960s he attempted to show that Einstein's geometric origin of gravitation was only one way to put a meaning into gravitation theory (Feynman *et al.*,1995), a thought right in line with Mach's teachings. He, among others, introduced by 1963 the idea of "gravitons" as an alternative for describing the existence of gravitational forces. Gravitation would be then a field with its own "particles" as electromagnetism had with photons. However, this track did not please his former thesis advisor. By 1973 John Wheeler reaffirmed with his "geometrodynamics" that there is no other way for gravitation to exist but through the geometry of space as Einstein described it, gravitons being incapable of describing *all* the physical aspects of Einstein's theory and require an unphysical "flat space" as a starting point for their theory.[15] While there is, as we have seen, and most likely, a fundamental addition to make in Einstein's theory, the fact remains that only one *coherent* way exists to think about the meaning of gravitation, the geometry of space. Nevertheless, to this day the idea of gravitons is still being considered by Quantum Field Theory.[16] It is thus extremely difficult to get rid of unphysical concepts purely via mathematical principles, an approach far removed from experimentation, and regretably one of the ways Science, by following Mach, has been attempting to discover fundamental things lately.[17] In fact, the logic of a mathematical theory may have an unchecked thrust of its own when no longer guided by imagination. As an example, Superstring Theory was invented in the 1980s out of purely mathematical considerations in order to explain the unphysical gravitons (Kaku ,1994, 1995). Maybe the pendulum has swung too far away from imagination in fear of falling into a sidetrack, or being plain wrong, when a formalism is not available. Conversely, it seems that "sound" imagination can also protect us from sidetracks when they are reached via perceived mathematical necessities.[18] As recent History will show below, we must above all guard ourselves against *imagination designed to buttress a formal theory that is wished to be correct for its own sake*.

As the 1950s seemed to nail down the coffin of metaphysical physicists, the biggest metaphysical idea yet to be dreamed of in Science appeared in the 1960s, thanks to Gamov, following an earlier guess by a priest, Lemaitre, under the name of the "Big Bang" (Hoyle's coinage per Gribbin, 1986). Science rediscovered Genesis! This grand dream came from a consequence of Einstein's *closed universe hypothesis* which was one of the bases of his theory. After all the progress made about understanding our reality along the thousands of years following the appearance of our civilization, this reality is now seen through the biblical Genesis concept, to the point that the Pope in the early 1990s at last forgave Galileo, 350 years after his condemnation, so that once again Jesuits are at the top of mountains watching the stars to read the mind of God.[19] And quantum field theorists, now objective allies of the Pope against Giordano Bruno (Mc Intyre, 1903), must push the Big Bang because it is needed for supporting their "effective field theory," an incomplete formal theory which includes the phenomenology of a "weak" field that would be there to connect the various elementary particles "flavors." (Weinberg, 1977, 1993, 1995, 1996) Indeed, we still don't know the origin of all the masses found in Particle Physics[20] and what "particles" and "fields," i.e. matter and radiation, really are, except items in meaningless formal expressions. "Hypothesis non fingo" is an everyday motto in this fundamental area of Physics. Also, a concept that envisions a beginning to all cannot explain this beginning itself except through some mathematical artifice, and thus can only give an incomplete understanding. It looks to be then a dead-end for the scientific approach, while leading to the end to all, the Big Crunch and Christianity Augustine's vision of doom on a non-scientific level.[21]

Here we have more than a cloud, we have a "storm over 20th century Science." No less than the foundations of Science were put in question over a century ago by Mach limiting the scope of Science's search to formal methods, and Mach seems to have at last succeeded. Sections III through V will address this storm through *the question of the elements making up our reality,* trying to find hints out of hunches expressed long ago in the history of Science by Bruno and Leibniz. These hunches have been forgotten by Science since they were only the product of the imagination, even though more recently Einstein belatedly remembered them, right before his death. (And this he did only via popularization articles, not "hard" publishing, as it seems he did not know what to do with such ideas, not having the crucial physical facts that were to be found after his time.) As to the question of the purpose of reality, we must first find a resolution to the other clouds in our understanding identified here before attempting an answer. It would seem more prudent.

D. The road toward a new understanding?

I can see from this storm that there are in fact two Fundamental Barriers that still have not been crossed in our understanding of reality, (1) the true *nature and foundation of this reality*, and, correspondingly, (2) the true *nature of our intimate perception of it*. This study will deal with the first barrier and its attendant clouds in our understanding. A separate study will deal with the other.

Early this century we have learned, and only now begun to understand with the help of Everett's imagination, that reality is built out of a world constantly searching many transitory realities, what is called the "quantum world." With the help of Feynman's hypothesis, and the Bruno/Leibniz/Einstein view that *space is constantly built out of its content*, this search may be conceptualized, as I shall initially describe in Section IV, as an "uncountably infinite parallel computation," with further discussions in Section V under the term of "extended computation," a computation that would be "uncomputable" by the Turing definition of computation (Turing, 1936). Even though this notion of computation was extended by Deutsch to quantum Turing Machines in the 1980s using the present Quantum Theory formalism, it appears to need another look as Nature may have an approach quite different from the ones humans have thought about so far.

Everett's vision portends a fundamental departure not only from the old Greek view of the world but also from all the physics and mathematics that has been conceived up till now, as everything in Science assumed a "flat" monovalued reality. This fact, being so new and different, has not been factored into today's Science, including Mathematics, even though experiments pretty well tell the story when the multiple reality point-of-view is used (Section VII).

First I shall investigate Everett's view through its consequences for Mathematics, by reviewing the physical meaning of the continuum (Section III). There I shall find that Mathematics is still essentially missing the new concepts discovered by Quantum Physics, as apparently mathematical inspiration still comes after so many years from concepts immediately obtainable from our perceived reality, i. e. the concepts of Classical Physics. Einstein was lucky (together with the world) to have had mathematicians before him who thought about curved spaces because he himself was not a mathematician as he advanced many times. Since now, unlike earlier times, the formalism seems not to be there (and this in a fundamental way) to buttress the advanced hypotheses, this study has no choice but to use an informal approach. Of course, the corresponding formalism can only come in the future if the understanding is sufficiently communicable for mathematicians to acquire it. Their role will then be to make it more precise to allow physicists to subsequently establish a formal theory with additional conclusions that would hopefully be experimentally verifiable. A process of establishing an understanding outside a formalism if the formalism is not there to support it in the first place is a sensible route for the scientific discovery process, as it has been used successfully many times before (the experience of Faraday is an example). In the end, reality may be comprehensible, but the understanding acquired through imagination and checked through experiments may not be fully formalizable (for example, can we formalize creativity?). Then the key will be to find methods that can capture the essential features of the understanding. If this cannot be done then we will have to go via empirical rules or heuristic methods to fill up the gaps of the formalism.

Then, through Section IV covering Feynman's unpublished idea, leading to the concept of a *universe built out of a computation*, I shall investigate in Section V whether a meaningful image can be obtained for the true elements of our reality. Space will indeed "materialize" through my mind's eye, instead of being an undefined ghost within Einstein's and Bohr's principles. Within such a picture, matter, radiation and space have a fundamental relative scale defined through their relations. Each is then a set of 3-dimensional spaces, constantly being generated through one another in the spirit of Bruno's and Leibniz's "monads," and producing a *3 times 3-dimension scaled relational reality* instead of the immediate (classical) 3-D space with no inherent scale.[22] This old idea will acquire hopefully meaningful details this time around. The hypothesis obtained in Section III that space is generated by its content will be then found to be experimentally verifiable through the physical absence of a formal entity postulated by Quantum Field Theory called the Higgs field. This would be a clear example of a finding requiring no formalism, only understanding. A similar (much simpler) example late last century was the Michelson-Morley experiment proving the absence of "ether."

The above world view will be applied in Section VI to the present problems of Astrophysics. There astronomical data will appear to confirm that *space is continuously generated and eliminated, with its own sources and sinks*. Such a concept could not have been considered in Einstein's lifetime since the "confined" and "free" qualities of matter/radiation were then unknown. Indeed, between the 1950s and the 1970s, Particle Physics has discovered the confining character of the "strong" field within atomic nuclei, the third field besides gravitation and electromagnetism (Gottfried and Weisskopf, 1984; Crease and Mann, 1996). But so far the *meaning* of such confinement and freedom qualities for the nature of the quantum, as well as for space and time, has not been addressed. Such meaning will be essential to the understanding described in Section V.

III. THE DISCRETE, THE CONTINUUM AND EVERETT'S MULTIPLE-REALITY

We conceived of numbers and magnitudes long ago: there are so many sticks in a bundle, and a stick can be longer, smaller or equal to another. Pythagoras took numbers as all-encompassing, but he was quickly desillusioned. As a result of the inherent imperfections of numbers, magnitudes and their *ratios* (thus their *relations*) became the basis of Euclidean mathematics, not numbers. The notion of a *continuum* came from the a priori notion of magnitudes. But this notion has also its difficulties. Taking over the discussion started much earlier by Greeks such as Aristotle and Zeno of Elea, Cavalieri and Galileo attempted to address them. E.g. from one of Galileo's manuscripts (Drake, 1978) of the year 1613:

"Understanding how the continuum is divisible into ever-divisible parts [Aristotle's own position], they [the philosophers] understand consequently that one part alone cannot be taken without taking innumerable parts along with it. But if that is true (as it is most true, and known to everyone having reason)..."

We see that our century's reason, namely Zermelo's Axiom of Choice in set theory (Courant and Robbins,1996; Bell,1992), goes against Galileo's opinion and perception of the nature of the continuum, as this key axiom of modern mathematics assumes that "one part alone" can indeed be taken from a set with the power of the continuum. I shall examine below the consequences of such a fantasy.

A "practical" (read "for the purpose of calculations"[23]) definition of the continuum came through the invention of the infinitesimals calculus in the 17th century by Newton and Leibniz. The 19th century saw a firming of the definition with the Cauchy/Weierstrass ε , δ description, followed by Dedekind's cuts approach for the definition of a member of a continuum, and finally Cantor's set theory definition through powers of sets.[24]

But the true nature of the continuum remains in question as in Galileo's time, and now more than ever as it looks to have once again a fundamental bearing on our understanding of physical reality. The quickest way to see the difficulty with the notion of continuum stemming from the Axiom of Choice is through the Banach-Tarski theorem (Bunch, 1997) by which it is shown that any volume can generate an infinity of volumes of equal size when the Axiom of Choice is assumed. Very much as for Euclid's fifth postulate unknowingly restricting geometry to only one of several possible geometries, this axiom may restrict mathematical analysis and topology to the point of making them irrelevant for Physics. There may be several types of continua, and, as in geometry, our physical world may be based upon only a specific type, maybe the only one that *does not lead to an impossibility when applied to reality*. It appears that this "physical continuum" is not of the kind so far described mathematically. Even when remaining in the realm of mathematics, Weyl, among others, has pointed out (Weyl, 1994) that the continuum as defined internally in Mathematics leads to a "vicious circle." As it has been the case many times in the past, once more *mathematicians must receive input from the physical world in order to produce theorizations that are applicable to it* (and of course they may go on their own way from there, but that's not Physics concern).

A. The nature of the physical continuum

Since the "volumes" obtained by Banach-Tarski manifestly do not match the character of our physical world, either our world is discrete (either finite or countably infinite - "contiguous" in Galileo's word) or it is somehow made out of an uncountably infinite set of *elements* superposed onto each other making up a "magnitude" such as a volume. As the quantum theory of radiation has shown (see more on this below), *our world cannot be discrete*. Then, in order to avoid the Banach-Tarski result, a volume needs, *from the start*, to be an infinite *superposition* of countably infinite "*discrete volume frames*" themselves made out of elements yet to be defined. The continuum considered is then "structured," and classical Limit Theory does not apply due to the *non-local* and *undistinguishable* aspects built in by these frames. This concept is not described by present-day topology as topology rests on a continuum defined through the classical Dedekind/Cantor methods, i.e. via the Axiom of Choice.[25] The manifolds of topology, differentiable or not, do not fit such a picture of the continuum, and polytopes don't fit either as mathematicians consider single entities, not infinite superpositions. Topology being the mathematical basis of General Relativity (Wald, 1984), it is no wonder that "quantum gravity" cannot be worked out using this improper mathematical conceptualization (this is not the only reason, Section V will give others).

The notion of "discrete volume frames" and their stacking into a superposition looks to be the key to a new mathematical analysis of our reality. The physical notion of "unseparability" found in Quantum Physics comes from a key feature of this stack of countably infinite frames: Once one of these frames is placed in the stack it cannot be retrieved without picking an *uncountably* infinite set of elements instead of the original countably infinite one. The Axiom of Choice in effect protected the validity of Cantor's diagonalization method because this method required the assumption that the elements of the set are "distinguishable" and thus can be ordered for use in a one-to-one correspondence, while a set made out of a superposition from the start needs not be ordered, and any attempt to pick a specific discrete volume frame can only result in picking an uncountable set, since it cannot be identified from another. Cantor's set has to be "separable" from the start before his method could be used. "Undistinguishable" and "indistinct" are very much the same thing as "unseparable," things cannot be separated because they cannot be distinguished, and ordering something needs distinction. Then Cantor in effect limited the meaning of "continuum" to an uncountably infinite set of distinguishable elements, as Classical Physics only considered at the time of Cantor. The quantum physical continuum with the notion of unseparability/ undistinguishability is in some sense more complete than the classical definition. Such a concept needs to be formalized as a part of a mathematics without the Axiom of Choice. Maybe it is too hard for the human mind to make it formal as it deals with separating qualities of infinites without using a finite bootstrap as the diagonalization method was. As a physicist, D'Espagnat discussed the concept of unseparability,[26] but his discussion was not very pragmatic in the sense of offering metaphors that could help mathematicians acquire its meaning. But there is no way to reach the goal without an intelligible set of metaphors.[27]

One metaphor could be as follows: The Cantor method fails to "wipe out" the identities of the items. The identity information disappears when one item is placed in the continuum. The superposition or stacking method provides for the wipe-out by entering a discrete volume frame in the stack at random, then I don't know where the item is, and thus *I can't pick it alone*, one item looks like the next, i.e. the picking process of one countably infinite item is impossible. Another way to express the same thing would be that the retrieval requires a countably infinite set of picks itself, and each pick then gets a whole countably infinite grid or frame, which may be in fact a new one not belonging to the original, but I can't know that fact as the frame's identity is not there, thereby I am forced to pick an uncountable number of them by the time I finish the "last" pick from the set of countably infinite picks. Of course that last pick is at aleph-not, so this is quite an unsound line of thought, but it "feels" right physically.[28]

In summary, *uncountability very much implies unseparability for the physical continuum as identified by quantum physics*, and thus such a "larger" continuum remains to be addressed by Mathematics.

B. Bruno, Leibniz and Einstein: "Space is built by its content!"

Then comes the question of the physical meaning of a volume. How can we "see" a single volume in our everyday experience if it is made out of an infinite superposition of discrete sets? The answer is that we do not see volumes but only their "containers" and/or their content. Today's Physics tells us that volumes are "arenas" (many terms are used, such as "scaffoldings" by Peter Bergmann, Einstein's assistant - see Bergmann, 1976) where the content ("matter"/ "radiation") of the world acts its mechanical or wavelike dance. But there is a fundamental difficulty involved with such a concept, a difficulty which was addressed only superficially by Einstein late in his life[29] (and not at all by his successors including present ones) as he advanced that

"the concept of space detached from any physical content does not exist...There is no such thing as an empty space, i.e., a space without field."

This was a late departure from the stands of his past concepts, in a sense rejoining the views of Leibniz and his monadic world as I shall discuss below and in Section V. In fact, from his field equation it can be concluded that a "flat space" can exist, namely a space without curvature, i.e. without a (gravitational) field. It is in fact this notion of flat space which is normally considered in order to reach the Newtonian Mechanics approximation, not to mention its need when gravitons are considered (Section II).

But this notion contradicts the existence of phenomena in a "perfect" vacuum, such as the Casimir effect, or the results of Quantum Electrodynamics which depend on the existence of "quantum fluctuations" in the vacuum[30] (the "zero-point energy"). There are always fields in physical space, even when it is "flat."

Also, the fact that the energy of the gravitational field is not only non-local but cannot be always identified locally, and certainly cannot be tied to the curvature of space (e.g. it can be in transitory "flat space" within a gravitational wave[31]) is an indication that this energy cannot be tied to space itself (via gravitons for example) but to its content.

We can only conclude, as Einstein did, that our physical world cannot be void of content: if we remove matter and fields there is nothing left, *not even space*. I shall venture to say that, even though he never stated it as such, it must have been this fundamental contradiction between his equation and reality that pushed Einstein into trying till his death to connect gravitation with electromagnetism, as electromagnetism must be somehow the generator of our space *if his equation is to make physical sense at all*. Well, he was on the right track, but he missed a few things, such as nuclear forces and their features.

So physical space cannot be an arena at all, but must be *the very result of the dynamics of its content, observable or not*, in line with Gottfried Leibniz's thinking in which space is a property of "things" and has no independent existence:

"Space is nothing else but an order of the existence of things observed as existing together, and therefore the fiction of a material finite universe moving forward in an infinite empty space cannot be admitted."[32]

A "flat space" then appears to be a conceptualization without a physical basis. Einstein's description of spacetime through his field equation must be incomplete, and this, not only at the level of the quantum as being thought by contemporary Physics,[33] but in a fundamental way. It can only be a drastic simplification of reality.

But the main features of the content of space must be then reflected in space itself. For example, as I shall describe in Section VII, the inherent "unseparability" of space described above via the rejection of the Axiom of Choice will be reflected in the non-local feature of the quantum, the "content" of space. This feature implies an infinite nature for space from the Banach-Tarski premises. Leibniz however understood his monads as finite entities alone with other finite entities. Giordano Bruno, more appropriately, understood the concept

"as independent infinite realities, each comprising the all in itself, as each is a necessary constituent of the all."[34]

So in order to define the make-up of reality the task will be to find how to identify infinite entities making up a larger infinite in some sense.

C. Going ahead without Mathematics?

This leads me to the fact that, unlike Einstein's case of curved spaces, no mathematician has considered beforehand space as being generated by its content, a concept quite inconceivable in a classical outlook of reality, and an outlook onto which mathematicians have hung in the past 70 years, maybe not knowing how to deal with a system denying the Axiom of Choice, as the quantum is pushing us into. Granted, this concept is indeed remote from an immediate perception of our reality that could be used in a metaphor to build an understanding,[35] and certainly more obscure than the previous one about curved spaces for which many metaphors are easy to construct. But it is not because mathematicians cannot deal for the moment with this idea that it must not be considered if Physics hopes to go ahead. If necessary, Physics may have to operate without the guarantee of Mathematics, maybe sometimes using partial formal systems at best, if physical phenomena that cannot be fully formalized need to be covered. In effect it would then rely more on empirical rules and experimental facts than on formal approaches, with the backing of a conceptual understanding to make sense out of them. I shall go that way for the rest of this study, but not before looking at a last formal approach that was attempted by Feynman in the past generation.

D. Everett and Dirac: *How* space is built by its content

The hypothesis of a multiple reality advanced by Everett (1957) at first sight seems to give a lead on *how* space is built out of its content since, as I discussed earlier, the multiple reality idea is inherently responsive to the mathematical necessity of a continuum definition without paradoxes. Conversely, the idea of space as built by its content could be *complementing* Everett's viewpoint.

However many questions have been formulated against Everett's vision, and this maybe because of its incompleteness about a fitting makeup for space and time. The criticism came in part from Everett's choice of quantum mechanical description through the Schroedinger picture instead of through the Heisenberg or

Dirac picture, but most of it seems to stem from Everett's inability to grasp key features of the quantum, which are its uncountably infinite (continuous) aspect, its "internal degrees of freedom" and the existence of different kinds of "forces" at the "elementary" particle level.

1. How Physics found out Reality is uncountably infinite

As Dirac pointed out (Dirac, 1966), the Schroedinger picture is inadequate for describing radiation. For him Hilbert spaces as developed by von Neumann in the 1930s (von Neuman, 1932) to mathematically support the Schroedinger picture of the quantum are inadequate for radiation because he assumed that *radiation is a continuum*, while Hilbert spaces cannot have an uncountably infinite number of dimensions. His own approach, via his (special) relativistic equation of the electron, is an algebraic approach that has been supported mathematically in part via Fock spaces. The Fock spaces of Quantum Radiation Theory that are obtained by defining *classes* of quantum states in effect reduce the uncountably infinite to a discrete number of dimensions. But these Fock spaces force us to consider group theory algebras (second quantization) instead of the functional analysis of the Schroedinger picture. From the early 1930s Dirac's approach was found incomplete as it could not handle phenomena dealing with the quantum fluctuations of the vacuum, leading to infinites in the calculations as a result of *considering the electron a punctual entity and radiation as a continuum of undistinguishable entities called "light quanta."* Three approaches were found at the end of the 1940s, whereby Quantum Electro-Dynamics (QED) was established (Feynman, Schwinger and Tomonaga), which "renormalized" Dirac's approach and removed the infinities. The experimental verification of this last theory was obtained with the best precision ever in Physics.[36]

It was recognized then that the theory could not give the true mass of the electron and its charge as a result of considering it punctual. In the 1980s String Theory revisited the matter by turning electrons into strings. But this story is not the concern here. All along the continuous aspect of radiation has not been questioned in Physics, especially due to the quality of the results in QED with such an assumption taken.[37] For Physics radiation is a continuum, and *a continuum made of undistinguishable elements*. The discrete aspect of the quantum simply disappears in Quantum Radiation Theory. Such a continuum assumption is then taken in this study as a fundamental hypothesis. How can Everett's constructive views be adapted to a formalism representing a continuum?

2. "Internal Degrees of Freedom" and "Strong Fields"

Within Electromagnetism, the dynamics of particles is described in the group theory (spinors) algebras mentioned above by the Dirac and Weyl equations (Gottfried and Weisskopf, 1986), where the formalism tells us in effect that we have "multicomponents" particles, two for the neutrino, and four for the electron, while the dynamics described through the nuclear strong fields of Quantum Chromodynamics (Yang-Mills "gauge" fields) requires six components for each of the corresponding particles, the quarks and the gluons (Gottfried and Weisskopf, 1986). Where can Everett's idea lead us here?

3. Keeping only the bare idea

In other words, in order to be applicable to our reality, Everett's vision must be extended to the continuum of radiation and to the subnuclear world, as well as must describe the "internal degrees of freedom" of the particles. All of this was not part of the original analysis by Everett. For example, the spin of the electron was not considered. Also, since Special Relativity is factored in the mathematical description of the internal components or degrees of freedom as is done in the Dirac equation, *the origin of time itself must be identified* within the new approach.

I find Everett's vision of a universe branching into multiple universes upon "observation," or David Deutsch's version of it (Deutsch, 1997) where the infinity of universes simply pre-exists since the "beginning of time," unworkable when considering the complexity of features that have been found in the make-up of our universe as mentioned above. My gut-feel also is that the ball has to stop somewhere in the multiplicity of universes. In any case, I cannot go further without establishing the *origin* of such multiple realities so I can tell, among other things, how our mono-reality appears.

Keeping then from Everett only the bare notion of multiple reality, I shall start a constructive approach for the make-up of reality by applying his concept to the most immediately visualizable, if not complete, formal picture of the quantum, namely Feynman's path integral approach.

E. Feynman: a last ditch effort at a formal approach

Feynman's non-relativistic "spacetime" approach to Quantum Mechanics (Feynman and Hibbs, 1965) allows the separation of time from the multiple and uncountable parallel trajectories of a particle, including its interactions with "fields" along its various ways, by using a "path integral" for the evolution of a given particle instead of a (Schroedinger's) differential equation. Such a description is however really equivalent to the Schroedinger picture, and is right in line with Everett's multiple-reality view, but it is better than Everett's original method, as a given particle is then visualized following an uncountably infinite number of trajectories in parallel in-between "observations," with a probability amplitude for each path tied to the Lagrangian of the particle through which interactions with fields and other particles are definable. Even though Feynman never looked at them this way (as he was forbidden by Bohr's philosophy to consider), these trajectories can be seen as "space-generating curves," unseparable elements in an uncountably infinite set, in other word a *space*, which the set of particles (massive and non-massive) creates for each other through their unseparable evolutions. Of course, the origin of such a space *creation* process will require finding out what the "particles" and their "trajectories" really are, a matter which will be discussed in next sections.

The various acausal "bubble-diagrams" found within Feynman's relativistic QED, that are resulting from "interaction with the vacuum" (Feynman, 1961; Mattuck, 1992), can be seen as some of the infinite parallel realities which, when superposed, give a total probability amplitude for the particle presence in space and time (provided a "renormalization" is performed, as the particles are considered punctual in a 3-D world[38]). However, in his QED, Feynman used a heuristic approach[39] to incorporate the relativistic Dirac equation for the electron in his path integral, and he was never able to modify his approach to reflect the "spacetime" aspect he originally wanted to formalize. Only the experimental predictions obtained from the approach justified it. Dirac was very adamant that this was no way to do science (even though a Nobel prize was delivered for it!), and Feynman agreed late in his life with Dirac. They both in effect agreed at last that *Bohr's and Mach's philosophies were only transient views: No theory can be scientifically valid or complete if it is not making sense to our imagination.* But it was time for others to pick the ball on this late conclusion.

As a matter of fact, workers such as Gaveau and Schulman (1989), right after the death of both Dirac and Feynman, did continue Feynman's imaginative search by considering the unpublished hypothesis by Feynman himself *where the material particle is assumed to go always at the speed of light*, and is subject to reversals of direction in proportion to its mass, thereby defining a "proper time" for the particle. The mathematics for such a formalism replaces ordinary space with a space generated by rotational group manifolds in the manner of "supermanifolds" as defined by Felix Berezin (1987). Then the algebra found in Dirac and Weyl equations for the leptons finds an equivalent in the path integral formalism.

But, as Schulman pointed out, this no longer is a "spacetime approach" as Feynman envisioned, since space receives an algebraic structure instead of an analytic one. This description nevertheless connects to Dirac's later views on the necessary algebraic approach (Dirac, 1966) to the quantum, and gives a matching picture where the continuum of space is the result of a superposition where the algebraic structure of space defines space itself at each instant everywhere in our reality.

I am going through the next section to delve into the *physical meaning* of this path integral formalism in order to prepare myself for the eventuality it is found in the end useless for dealing with all the facets of reality. The goal will be then to go beyond it through a strictly conceptual approach.

IV. THE SPEED OF LIGHT, AN ABSOLUTE BASE FOR A RELATIONAL REALITY

A. Why is the speed of light a barrier?

The constancy of the speed of light (really the speed of any electromagnetic radiation as well as the spread of any disturbance of space) as measured by any observer is a fundamental characteristic of reality, and at the origin of Enstein working out his theory of principle called Special Relativity. Yet the origin of this constant speed is so far unknown. I shall propose that it is a logical necessity that can be understood via a well-known paradox. As the Banach-Tarski paradox led me to multiple-reality, a paradox from Zeno of Elea, the famous ancient Greek, will lead me to the necessity for a constant base, defining speed from which time and "motions" can be constructed. It is called the paradox of the Stadium (Bunch, 1997). Briefly, there are three rows where the A row consists of spectators, and the B and C rows consist of runners in opposite directions. Row B moves *in the shortest possible time* T left and row C moves in the same time T right. Within this time row C will have passed two runners of row B, so passing one runner takes T/2. But time T was assumed to be the shortest possible time, thus T/2=T, and I can only conclude that T=0. This tells me that time intervals cannot be consistently defined, and thus time cannot exist, which is the conclusion of Zeno, but I add: for moving objects going at the fastest speed. Therefore time can only exist for objects that constantly reverse their direction of travel versus others, and thus *average speeds in a consistent reality must be less than a base speed of objects for which time cannot exist*. Such an approach identifies time through relative motions between objects, and so a *relational* reality is necessary, that is, I cannot pick an object out without picking its relations with others. This seems a fitting complement to a space continuum that rejects the Axiom of Choice as described earlier.

B. Feynman's hypothesis

Feynman toyed in the 1940s and 50s with the idea that *everything in fact goes at the speed of light* and we must work out our reality from there (Schweber, 1986). Without knowing what they truly are, "particles" with a *mass* can be pictured merely performing a sort of Brownian motion changing constantly direction of travel in proportion to their "mass." Under such a picture, inertia is *locally* defined by the make-up of the massive particle, not by its *cosmical* origin (whatever that was) as Mach's Principle of the turn of this century envisioned.[40] Then any particle "proper time" does not exist since it is always going at the speed of light. Time for a particle gets defined only through its constant *relations* with the "particles" it "interacts with," *across the space generated by the multiple trajectories of these particles*. At this fundamental level time cannot be defined independently of the particle, and thus cannot be a coordinate as conceived in the spacetime of Relativity.

And so it is for space, as the mathematical notion of "neighborhood," as found in the foundation of classical Topology,[41] cannot be applicable here. Space is defined through the infinite set of trajectories of interrelated entities called particles, trajectories which cannot be space-filling curves a la Peano, that is, locally defined and part of a "flat" reality, but non-local "space-generating curves" in the sense that they define the *space of the relations* of the particle with the other particles. At this point I am reaching an apparent contradiction through the terms "particles" and "trajectories" as they require that a space exists beforehand. Next section will replace this inadequate picture with another concept, *monadic relations*, which can only be imagined by denying the Axiom of Choice, whereby I cannot pick one part of the relations without picking a sub-part of the same cardinality as the whole.

To connect this relational reality with its *transitory aspect* I take the simple example described by Feynman (Feynman and Hibbs, 1965; Schweber, 1986) of a particle "moving" in one dimension going only forward or backward at the speed of light. Feynman defines the *unit of time* as h/mc^2, being the interval between "events" when the particle *may* change direction. This unit of time is specific to the particle and gets smaller with a larger mass such that there are more events for a given "total time," which is yet to be defined. Mass then appears as defining the particle "propensity" to experience events where a motion reversal can occur, and thus is an inherent character of the particle. Feynman does not go further in explaining this propensity. Gaveau and Schulman identify this as a "hypothesis non fingo" position (Gaveau and Schulman, 1987, 1989; Jacobson, 1984). Yet it is fundamental to the dynamics of the particle. Feynman also does not identify the reference frame in which the "total time" is measured. I could infer that it is the particle "rest" reference frame if I follow Special Relativity, but the particle goes at the speed of light where time does not exist, and thus this inference leads to a contradiction.

C. Our Reality, some kind of computation?

The only way I can see out of this dilemma is to understand the "evolution" of the particle as a *step process*, i.e. a *computation* where the outcome is defined by the particle's prior relations with the other particles, themselves performing their computation through which they are laying out the space for the particle under consideration. We are then dealing with discrete "events," joint ("non-local") happenings where there is *a "before" and an "after" defined by the change in configuration within the system the particle belongs to* at the event. This picture is another way of seeing the continuum defined as a stack of "discrete volume frames" (Section III). A superposition or stack of such frames represents the system having the discrete "events" above, and a "step" then follows each event.

In this picture, and as the next section will further describe, our ordinary space is a computational space which is inherently transient in existence through an uncountable infinitude of parallel computations made with chains and trees of "monadic" relations. A monadic relation has an input and an output defining the before and the after for that relation, the before being the input, and the after being the step. In the next section I shall look at the nature of such a computation (of course only qualitatively and within a physical viewpoint).

D. The problems with Feynman's approach

Then Feynman introduces an electromagnetic *field* acting on the particle. This can only be interpreted as a "mean interaction" with the "surrounding," not specific relations between particles. But fields are "continuous" entities in the classical sense of the term, requiring the Axiom of Choice for their formulation. Therefore the use in that sense is inconsistent and I shall only take the term as an assembly of things to be defined further. Using the classical meaning of the continuum, Feynman comes up with the electron relativistic Dirac equation in one dimension, thus advancing that his picture may have nevertheless some physical basis. This thesis however can only be a crude description because:

1) it assumes a "flat space" since the unit of "proper time" only reflects Minkowski's spacetime of Special Relativity, not Einstein's curved spacetime,

2) there is no spin in one-dimension space, i.e one-dimensional spacetime has no true physical basis,

3) the particle propensity to experience motion reversals is unexplained,

4) the origin of the process total time is not relationally defined.

All these shortcomings except for the second cannot be handled without considering monadic spaces as I shall do in the next section.

E. A minor fix

Gaveau and Schulman (1987, 1989), after others' work in the 1980s (Jacobson, 1984), have addressed the second shortcoming, i.e. Feynman's picture in 3-dimension space. In the case of the electron, a fermion, there are four "internal" components,[42] each two with a dynamics that would follow the Weyl equation of a massless neutrino[43] if they were not "coupled" via terms corresponding to the mass of the particle. These four "spinor" components of the electron have a resulting dynamics collectively following Dirac's equation.

Then, within a particle trajectory, time gets defined for the particle through *direction reversal events at light speed*, a process formalized as an average of a statistical Poisson process parameterized by its mass. Besides direction reversals coming from its mass, the particle has a stochastic motion through a *contiguous* series of two rotations in twice-connected SO(3) spaces, or SU(2) spaces as they are usually identified within the Lie group algebras of "local transformations." Each set of two rotations is then found equivalent to a translation within "ordinary" (our common) space. The notion of time is independent from this algebraic description as the proper time of the particle cannot be defined by such a stochastic process. In the spirit of Feynman's paths and Everett's multiple realities these two different processes can be viewed as a set of chains in lieu of trajectories for the particle. But then ordinary space can be seen as constantly being generated by these chains of elementary SO(3) spaces rotations, and identified to what has been called a "supermanifold" by Berezin (1987). The fundamental consequences are that (1) there is a "fine structure" to our space and (2) more than 3 dimensions are needed for this structure. We are dealing with a Lie algebra of rotations, giving a Grassmann algebra of translations instead of translational "magnitudes." The picture of a topological continuum for our space is then incorrect, our space being dynamically generated through an infinite superposition of chains of rotations in dimensions that are outside our ordinary space dimensions. This continuum cannot be defined locally, and present-day mathematical topology cannot be used as it considers "neighborhoods" in its definition (see Section III). A given particle (a manifold of relations) could be within one reality at a distance from another of its realities *outside* the light cone of Special Relativity. Then the particle may have, through its various realities, relations with other distant particles, thereby relating itself to parts of the world outside its own light cone ("spacelike" events with no causal connections). Quantum non-locality beyond the causality limitations of Einstein's relativity is thus a fundamental feature of our reality[44] that fits Bruno's picture of the monads. The multiple-reality monadic space view described in next section will then give a tentative (and constructive) origin for this feature. I shall discuss in Section VII what this entails in physical effects.

F. The old formalism can't be fixed, so let's go on!

The other shortcomings of Feynman's picture have not yet been addressed by Physics. In effect a speed less than the speed of light is the result of a statistical Poisson process, as if there was a "medium" through which the particle goes through, "slowing it down."[45] It is a scalar process separate from the stochastic rotations through the SO(3) spaces, which do not affect the time of the particle. The SO(3) spaces naturally support collectively the phenomenological picture of an electromagnetic field (virtual photons) generated by the particle, and interacting with the particle itself, as well as generated by other particles. The set of trajectories or chains, or computational tracks, have each a separate time for their evolution as a result of the "mass process." This is where Feynman's path integral approach is incomplete, and Gaveau and Schulman's is also incomplete. The path integral cannot be on a time definition common to all the paths. Each path has its own time evolution. But then a Lagrangian can no longer be defined and the entire formalism of an "equation of motion" unravels. Physics therefore can no longer use this centuries-old formalism, as it is simply inadequate for a quantum process that generates its own space and time.

Bypassing this question of formalism and resorting to a logical and physical exposition, I shall describe in the next section how the scalar process of time definition not only can lead us to the origin of mass/inertia, and consequently gravitation, but also to the origin of the existence of the quantum world. To this effect, there is no other way but to obtain a logical picture that can explain the "Standard Model" of Particles Physics using fundamental elements, the monads, instead of using the set of formal (non-constructive) principles of today's Physics.

V. THE RELATIONAL BUILDING BLOCKS OF SPACE AND ITS CONTENT

The picture started by Feynman in the previous section provides a sketch of the process behind electromagnetic phenomena, but there are three problems, one of them describing a "medium" where a particle is subject to a Poisson process, but with no causal source. To identify such a source I shall first look at the other process, generated through the SO(3) rotation spaces, that the particle is also found to go through. I am then in effect *singling out* one "particle" among a collection of rotating spaces generating our 3-D space continuum we call "vacuum," and these SO(3) spaces themselves can be seen as the result of relations between the given particle and other "particles" commonly called "virtual photons."

A. The road to monadic spaces

1. From a Berezin integral over an algebra to (unseparable) monadic relations

Can I imagine a *set* of SO(3) spaces generated by the "components" of the particle themselves rotating versus each other? Yes, if one of the consequences of this larger "rotation" versus our ordinary space are reversals or changes of direction of the relations of the whole with our space. This assembly of SO(3) spaces would then be an unseparable set of elements (Fig. 1), which I shall call "monadic spaces" in reference to the *monads* Bruno, then Leibniz, postulated long ago[46](Section III). The existence of such spaces rests on their relations among themselves, very much as a thesis and an antithesis lead to a synthesis, but thesis and antithesis are such only because they are immaterial entities *unseparable* from a "train of deductions," i.e. an infinite number of elements of the same kind that infer one from the other. The monads can be seen then as a set of root/tree systems leading to a multiple-reality superposed on top of each other, giving a continuum (Fig. 2). Such propositions are independent from each other and thus define relative orientations *isomorphic* to orientations in a pre-existing 3D space (Fig. 3). However here there is no pre-existing space as *these propositions define the directions only relatively to the other propositions, nothing else exists, not even a pre-existing "space."* Instead, *each proposition can only exist in a space created by all the other propositions.*

There may be a correspondence between this unseparable set of relations with an integral over an algebra since the integration process as an uncountably infinite iteration connects all the elements of the integration as an unseparable whole.[47] (I note here that through a correspondence between iterations and recursions this integral formalism may have alternatives in a system that rejects the Axiom of Choice.) The algebra of rotations then corresponds to a set of the above deductions, the *monadic relations* (Fig. 1) within a root/tree system of all the possible realities. Our reality is then a subset of all the resulting common "deductions" process between irreducible entities that get defined only through their inter-relations, very much as recursive functions are defined solely through their relation with other instantiations of their own selves. (Davis, 1973)

2. From monadic relations to a non-Cartesian set of unseparable space manifolds

Each assembly of monadic spaces relates to other such spaces in multiple ways, each way corresponding to a reality of that space. These multiple ways are infinite in number, in fact uncountably infinite since powers of sets are involved. The only given in this space definition process is its number of dimensions, which is the maximum number of independent orientations the monadic relations can take versus each other. Only three dimensions can be used for the independent components of a "deduction." But each ensuing proposition can be in a different set of 3D (Fig. 3), then the unseparability of the system needs not be complete. In fact there must be a decomposition, a separation in parts *that monadically relate as wholes to each other*, where all the possible relations between the parts exist, each a "reality" for the part. I then need three times the original set of dimensions to build such higher level relations while each part remains itself an *unseparable manifold of monadic relations*. Being a set of relationally defined spaces, this set itself cannot form a 9-dimensions Cartesian space since this last kind of space breaks down (separates) in independent parts in the algebraic sense of its various dimensions, which is manifestly not the case here. Each manifold is some sort of "curved space" in the Gauss/Riemann fashion (assuming a correspondence can be established between different types of continua per Section III). Diagrams such as Fig. 4 cannot be correct since, besides the number of dimensions involved, the relations are not in a pre-existing Cartesian space. Further mathematical insight on how to represent monadic relations manifolds will help in this matter (if they can be represented at all). Later sections will give physical examples which could also help in making up a representation. The manifolds relate to each other through their essentially dynamic "connections." Both connections and "curvatures" of manifolds will be discussed below.

3. From a non-Cartesian set of spaces to particles and their "internal degrees of freedom"

Since such space manifolds are relationally defined, *one of them must be the set of connections making up all the realities of the other manifolds connections, thereby effecting the base reference for all these realities, the relational "bond" between all the other manifolds, which then can be perceived as the "content" of this common space manifold (CSM).* This manifold may correspond in some fashion to the space-like slices of the spacetime described by General Relativity. But the connections between manifolds are not punctual, they are "continua" with a measure *across* their various realities (Fig. 5 and Fig. 6). Of course such a "measure" concept is now quite vague and will have to be framed in an extended definition of a mathematical measure for "physical continua" since neighborhoods cannot be defined across non-local realities (as discussed in Section III).

Then, by its nature, the CSM will allow the separation of content space manifolds into "particles" with "paths" or "trajectories" through their connections with the CSM. This picture will require a formalism generalizing the path integral used earlier in order to represent the unseparability of the various realities. This unseparability of the uncountable infinitude of realities for the so-called particles will provide them with a "non-local" behavior. Such a feature can be perceived as characteristic of a "quantum world," a world resulting from the multiple-reality aspect of the monadic spaces, coming from the multiple relationships between spaces in different sets of 3-D's.

Next I have to deal with the relative orientations of the content manifolds versus the CSM, what ordinarily is called the "internal degrees of freedom" of the "particles." This aspect of inter-space relations will require identifying the CSM with ordinary space and treating it as the differentiable manifold of the Einstein/Riemann picture (Misner *et al*., 1973), allowing then the use of the Lie Group theory (Joshi, 1977; Wybourne, 1974) to deal with the orientations of the content space manifolds. This will also require a correspondence where the monadic spaces and the rotations they represent are turned into *sets of monadic relations "tiles" covering the manifolds* (Fig. 1 and Fig. 7). Such a correspondence can be visualized using intersections of close-packing arrangements of identical spheres (the SO(3) rotations) as images of monadic relations in 3D.

I shall use this last tiling picture instead of the SO(3) spaces to develop further the understanding about monadic spaces. The tiling concept (even when 2D is used as I shall do below) allows representing both the "local" and the "global" characters of a manifold of relations. It is of course a crude way of description but it simplifies the wording facing the fact monadic space manifolds cannot be correctly represented as mentioned earlier.

4. The inherent scale of our reality, its time flow and relation to the origin of masses

Another fundamental aspect of monadic spaces is that they generate "translations" with no absolute length or time attached to them, a logical deduction having inherently no corresponding length or time. Time and length are created relationally (1) through the number of reversals (reversed logic) experienced by the "particle," that is, the whole made up by the monadic spaces, and (2) through the SO(3) spaces rotations that result in translations having a length fixed by the size in number of monadic spaces making up the "particle" space manifold. The formula h/mc^2 for time intervals in the earlier Feynman picture reflects these definitions. h is the Planck constant which can be understood as the angular momentum of the particle space manifolds as they rotate (of course at light speed) versus the CSM. This constant appears as a *ratio* with the mass of the manifold, therefore the mass of the electron is in fact defined by the *scale of our reality* and vice-versa.

Then where does the specific ratio h/m obtained experimentally come from? The mass (inertia) being an intrinsic character of the manifold making the particle, it can only come from an inherent *asymmetry* of the monadic arrangement. When there is no asymmetry there is no mass, such as for the photon. At this point I am reminded by D'Arcy Thompson[48] of an old Euler topological problem about the tiling of a sphere (or any closed surface) with hexagons.[49] Unless the sphere has an infinite radius it cannot be tiled only with hexagons. There must be some pentagons and/or heptagons to complete the sphere. The existence of different tiles breaks up the symmetry of the manifold (Fig. 7).

5. Resolving Feynman's problem #3

Such a feature provides the cause of Feynman's postulated reversals in direction for the translation of the manifold ("massive particle") interface in the CSM: If the CSM is itself tiled with hexagons, then a pentagonal series of "deductions" ends in a different orientation for the succeeding "motion," the CSM hexagon being not completed (Fig. 7). When this is generalized to manifolds, the ratio between the number of non-hexagons to hexagons relates to the curvature of the manifold formed by the tiles. The mass m then comes directly from this ratio. The only parameter left is the size of the manifold itself, which is defined through the number of its tiles, the monadic spaces, size which corresponds to h. Then the ratio h/m defining time *for the particle manifold* is fixed. The inverse of this ratio m/h is the physical quantity representing inertia *at the quantum level*, not the mass itself, a fact wich has been experimentally verified through interference effects in neutron interferometers (inertial and gravitational mass have also been verified equal that way[50]). Thus for quantum phenomena what counts is the definition of the average proper time for a massive particle (its own time) *h/m* across the realities of a quantum, and a *consistent* time definition *across quanta* then must be at the origin of gravitation. This consistent time is the time coordinate of "spacetime," being the result of a computation in an extended sense as I shall describe at the end of this section, *and not a predefined "coordinate of a physical process" at all*.

6. The sources of multiple realities

Space manifolds connections to each other can be multiple, and when a content manifold is asymmetrical (massive) it has *different* ways to relate to the CSM and such ways must be all realized. Later on another source of multiple realities will be identified.

B. Relations with existing concepts

1. Today's concept of mass

Physics[51] describes fields as corresponding to a mass, yet the photon has no mass, and in general the argument over how the mass of a particle needs to be relativistically treated (fixed or variable) shows that Physics yet does not know what "mass" is after so many years. The picture developed here takes the fixed mass understanding that Einstein belatedly described, and which is to this day not reflected (or at least misdescribed) in many textbooks.[52] Correspondingly, in quantum physics time is treated as a parameter unlike other variables of the system which are "operators." This reflects the fundamental incompleteness of quantum theory when it comes to spacetime.

2. Constants of Nature

As Lee Smolin and others have pointed out (Smolin, 1997) our universe can probably be defined by a few parameters. The *relative* size of a particle manifold represented by *h* may be one. Other parameters have to do with the relative curvature of the various "lobes" making up the particle manifolds as they will be described below. Under the monadic space picture the CSM must be made out of the same monadic elements as matter and radiation. "Elementary" particles of a given kind then must have all the same characteristics, and the "constants of Nature" such as *h*, *e* and *g* must be truly constant as a necessity of the monadic spaces computation. The whole determines the parts, and conversely, in a recursive fashion. I shall discuss later on how the "birth" of a massive quantum would come about in such a fashion.

This is the multiple-reality monadic space concept answer to a question asked by Dirac (1978). In contrast, it is well known that, in the initial "singularity" hypothesis (the Big Bang) electromagnetic, strong and gravitational forces strengths become of the same order of magnitude at enormous energies, and so under such an hypothesis, the "constants" are not really constants. But the fundamental meaning of "energy" itself is undefined through this approach (not to speak of the meaning of space and time), and thus this whole line of thought is incomplete and may be then ultimately unsound. Smolin's vision of a Darwinian universe evolution, where the constants are selected at random within a range of possibilities, belongs to such a line of thought.

3. The formalism of Quantum Theory

The term "quantum" has replaced "particle" and "wave" in quantum mechanical terminology under the influence of Dirac, but yet today's Physics cannot explain what is a "quantum of energy," that is, what are the constructive elements (the ontology) behind this term. In the view laid out earlier, *a quantum is a monadic space manifold in its own 3-D that has infinitely multiple connections with the CSM as well as other quantum space manifolds in their own 3-D*. "Energy" refers to the number of *spatial-wise duplicated* (identical) connections (realities) of the monadic space manifold. This last concept will be given more details later.

As a result of their infinite multiplicity the undistinguishable ***connections*** *of the quantum may be formally treated in a statistical manner even though monadic relations are fundamentally determined.* Such a method of course entails a loss of description, a simplification, the major areas of loss being about the generation of the CSM and its content manifolds, *resulting in an impossibility to treat any physical process involving the internal configuration of these manifolds of relations or relating content manifolds with the CSM, i. e. gravitation or possible CSM structural alternatives* (I shall give later a potential example of such alternatives).

The orientation of a (bounded) massive quantum manifold versus the CSM depends on the amount of "travel" (the number of steps) through it. There will be a *phase relationship* across the realities of the quantum that will allow them to substract or add to each other's monadic relations with radiation manifolds wherever their realities are connected in the CSM (Fig. 5 and Fig. 6). This property can be visualized as an algebraic sum of rotations represented by 2-D connection tiles between the massive quantum manifold and its "surrounding" virtual photon manifolds involving monadic "reverse logic." The massive (asymmetrical) quantum realities connections can then be attributed a probabilistic wave behavior through a complex number, a "probability amplitude," translating its modulus into the quantum "probability of presence" across the CSM for a given proper time of the quantum. The "wave function" ψ is then the catalog of all the probability amplitudes at a certain time (Schroedinger's definition) for the various instantiations of the quantum realities connections. Such a picture has shortcomings, as I shall discuss later on.

Non-massive quanta are the spaces (SO(3) for virtual photons) through which the massive quanta go through in their "travel." A "real" photon is a multiplicity of such spaces that "travels" via the tiles of monadic relations within the CSM (tiles that of course belong to other content manifolds).

The phase relationship for a massive quantum represents an invariance of the wave function across space (the CSM):

$$\psi = e^{i\chi}\psi' \tag{5.1}$$

and thus is a U(1) symmetry of the four-spinor components function ψ. It formally represents the existence of an electromagnetic field, i.e. virtual photons, where the set of realities making up the massive quantum follows Dirac's equation in its system of two-spinor components equations form.[53] The e-m field is then a "phase field."

The more general term "gauge field"[54] is used when the transformation above is replaced by

$$\psi_\alpha = U_{\alpha\beta}\psi'_\beta \tag{5.2}$$

where U is a multicomponent operator instead of a complex scalar. A 3x3 complex matrix representing a SU(3) rotation leads to the strong field of subnuclear physics where any one of 3 different "charges" called "colors" are required for each massive particle (the quarks) and virtual field bosons (the gluons). U either changes the color of the particle or acts as a phase-changing scalar like the e-m phase factor.[55] The wave function has then three sets of spinor components. These mathematical findings fit the 3-D monadic space manifolds picture hypothesized earlier for quanta, and will allow to guess at additional structures for these manifolds.

C. Differentiating things

I am then going below to interpret the experimental data known from Particle Physics to distinguish there what makes the strong field a special feature of monadic spaces, a feature which will be one of the bases for the creation of a new world, the "classical world."

Even though Bruno and Leibniz foresaw the existence of monads, they both were stumped on how a differentiation between them happens. This is where the knowledge we have acquired recently in Particle Physics becomes useful. As I shall describe below, we found in effect that there are two kinds of relationships between monadic spaces, the ones creating bounded common spaces and the ones creating a single unbounded manifold common to all, the CSM. This feature comes from the 3 times 3D arrangement into which the monadic spaces must place themselves by their fundamental nature. The various "quanta of energy" they form then further "coagulate" into entities with somewhat fixed locations of their connections with the CSM, thereby creating a "landscape" of some sort in that CSM from which everything can be then relatively defined. The differentiation of locations still will not provide distinguishability. This won't happen until additional features are created through sets of quanta monadic relations.

D. The Standard Model and monadic spaces

1. The electromagnetic field and its space

Photon/electron relations (which I call "electromagnetic" relations) are then relations between monadic space manifolds outside our 3 dimensions (outside the CSM). The electron monadic space manifolds in their own 3-D have an *orientation* vs. photon space manifolds in their own 3-D, and all orientations are existing in the infinitude of their realities as a probabilistic wave with phase relationships across the CSM and a time, which will need to be further defined, describing these orientations. Half integer spins originate from the 2-D connections between the particle manifolds and the CSM (only one speed exists for the manifolds rotations versus each other, thus spins come in fixed values tied to $\hbar$). *These connections must remain in the same plane of the CSM while the electron manifold rotates in its 3-D because of the "reversals" in direction in the CSM* (more precisely, changes in direction defining a plane - Fig. 7) *as a result of the electron manifold non-zero mass (asymmetry)*. A SU(2) rotation, i.e. a twice connected SO(3) rotation is then experienced within the CSM.[56]

This feature and the existence of two "parts" in the electron manifold (Fig. 8) can be perceived from the Weyl equation system form of the Dirac equation where a coupling between *two* spinor sets of components exists through *mass terms*. In this picture neutrinos space manifolds must have a single "part." *These last particles must have a mass, however small it may be*, in order to explain their half integer spin, i. e. their "internal" SU(2) rotation (Joshi, 1977; Wybourne, 1974). In general, truly elementary particles with a mass must have a half integer spin, and vice versa. I note here that the Standard Model cannot answer whether neutrinos have mass, while recent experiments prove that at least some of them do have a very small mass versus the electron (muon neutrinos - Kestenbaum,1998).

Having no mass, photons have intersections with the CSM that are not required to remain in the same plane. They then have SO(3) rotations versus the CSM, resulting in a *unity* spin (Fig. 6). The frequency of a photon is the result of its manifold realities multiplicity, which can only be a multiple of its manifold number of monadic spaces as reflected by the Planck constant *h*. The manifold can be then visualized as made up of many layers of monadic spaces, higher the number of layers and higher the frequency, thus energy. The various realities of the photon operate in concert reflecting the fact photons can only go at one speed. The connections of a photon travel as a classical wave in the CSM until the photon monadically relates to massive particles. On the other hand, the layering in realities of a massive quantum is spread out through the multiplicity of its paths resulting from the reversals in monadic relation directions, itself coming from its internal asymmetry (mass).

2. Matter-antimatter

Dirac's equation also identifies two sorts of massive quanta, "matter" and "antimatter," through which he understood positive and negative energies. Others have thought later that, instead, the solutions of his equation in fact identify reversed "charges," and both matter and antimatter have a positive "energy," there are just positive charge electrons and negative charge electrons. However this does not tell what "electric charges" are. The picture of monadic space manifolds gives one explanation. Dirac's picture allows to advance that "charges" reflect the double connections of the particle manifold with virtual photons manifolds in their separate relational 3-D. The two spinor components of the particle correspond to four lobes of its space manifold, in two "sets of wheels" using Bucky Fuller's colorful terminology,[57] which can rotate versus each other one way or the other through the intermediary of a photon manifold. The electric charge corresponds to the ratio of rotation imparted by the virtual photon on these two sets of wheels, while the spin of the electron is the overall rotation of its manifold versus the CSM. In one set of directions for the relative rotation of its lobes, the electron manifold will move in the direction of the photon travel, and in the other it will move in the opposite direction for the same SU(2) rotation versus the CSM (Fig. 9). Matter and antimatter correspond then to opposite orientations of the particles manifold lobes versus the CSM. Photons and anti-photons are identical as they are symmetrical versus the CSM. Matter/antimatter reactions give out photons since the symmetry of the involved manifolds is restored through their merging.

3. The Exclusion Principle

This picture provides also the ontology behind the Pauli Exclusion Principle. An electron in a given spin state around an atomic nucleus will emit virtual photons that can interact only with electrons of the opposite direction spin. Electrons with the same direction spin will not be able to get into the areas where these virtual photons realities can be found as they won't find matching monadic relations on their way. Such a feature can of course only work around a given nucleus as the system is then synchronized via the nucleus virtual photons and localized states for electronic quanta can be defined. Electrons away from nuclei are not subject to this exclusion effect as they have no definable state (this would not be applicable to electrons in solids where the Exclusion Principle and thus Fermi-Dirac statistics applies through the overlaps between atoms electronic orbitals - Jones and March, 1973).

4. The strong (nuclear) field and its spaces.

Sub-nuclear worlds (nuclei of atoms) are based upon a local SU(3) rotation symmetry for their monadic space manifolds versus the CSM that limits the extent of their evolution in it (the "confinement" feature in the Standard Model[58]), contrary to electromagnetic relations which are spatially unbounded. This can be understood through the fact that the SU(3) symmetry is the one of the 3-D harmonic oscillator,[59] with the "force" between quarks constant, except when approaching the common center due to "anti-screening" (the "asymptotic freedom" feature of the Standard Model[60]).

The system cannot break into isolated quarks and gluons since the components can only "move" in relation to each other, and thus the system *creates an isolated space for itself*. This can also be seen if I consider for a moment an isolated "colored" component, the force it generates becomes very large with distance, thereby creating a new set of colored components neutralizing the initial color and forming a new isolated space by themselves.

The quark manifolds have three "sets of wheels" instead of two as allowed by their own 3-D configuration. The "charges" corresponding to their evolution must have three different versions, one corresponding to each group of two sets of wheels, and are called "colors" in the Standard Model. The "gear" for such an arrangement called a "gluon" can be pictured as a curved tetrahedron with each face lobe having two possible directions of rotation, thus there are eight possible gluons, six changing quarks color and two effecting an electromagnetic field. Because gluons have three relative internal rotations between their lobes they have a color charge like quarks and unlike photons. But, like photons, gluons having lobes in the same set of 3-D can't have monadic relations among themselves ("glueballs" cannot exist, contrary to a hypothesis made within the Standard Model context). Leptons and quarks interact among themselves only via photons and gluons as they cannot have direct monadic relations being all in the same 3-D.

Only when the set of quarks and gluons is "colorless" will relations with photons enter in the picture for the overall motion of the set, and then the nucleon or nucleus will act as a composite system (including the space it creates) that is subject to the electromagnetic field and will move through photon "gears" in the e-m field-originated CSM. This is reflected in the mathematical fact that SU(2) rotations are subgroups of SU(3) rotations. In effect *nucleons and nuclei create bound spaces that relate as wholes (composite systems) with the surrounding e-m-based CSM* through their virtual photons to contribute to its creation.

5. Localized quanta

The *bounded* (spatial-wise) nature of strong (nuclear) forces breaks the symmetry of the CSM such that *differentiated localities* and *differentiated orientations* can be defined relative to them. This is because nuclei have no direct means to be synchronized with each other as their "gear," the gluons, require complementary structures called quarks, the massive quanta in nuclei, and thus must remain within a bounded space (which they create) defined by a necessarily "colorless" set of quanta as I discussed above. The strong forces monadic computations within different nuclei update then in an unrelated manner vs. each other. They are then like non-synchronized separate computer processors in the computation making our reality (Section IV).

In light of this feature I shall define "localized quanta" as nuclei of atoms together with their surrounding electronic quanta shells and the associated virtual photons resulting from the e-m charges they carry.

6. The second source of multiple realities

Two monadic spaces features can be seen as sources for multiple realities: (1) as seen earlier, the relational multiple evolution originating from necessary massive monadic manifolds asymmetries that can act on the path of a "particle" manifold only through its *multiple ways of connecting to the CSM*, and (2) the true spatial separations resulting from the strong forces, themselves originating from "confining" monadic relations, creating separate spaces with no direct monadic relations between each other (atomic nuclei), which have then also *multiple ways for connecting to the CSM*.

Within condensed matter the number of possible realities may be only slightly reduced (in the case of insulators) by interactions between the orbitals of the various electrons belonging to each atom because the time scale of strong forces monadic relations updating is much shorter, in the order of 10^8 times faster than the electromagnetic ones.[61] These original multiple realities then move in a "sea" of non-massive monadic space manifolds and thereby spread their multiple connections. These non-massive manifolds (photons, real and virtual, being in the e-m CSM) do not generate multiple realities. Real photons are already an uncountably infinite multiplicity marshalled and dispersed by massive particle manifolds during their transition from one state to another within localized quanta. They just spread, get divided, regroup in their evolution through monadic relations with massive particles (Section VII will give examples).

7. Relations between families and flavors of particles ("weak" fields?)

The three families of flavors for leptons and quarks identified in the Standard Model are necessitated by the 3-D character of the particles space manifolds within the 3 times 3D non-Cartesian set of monadic space manifolds and their internal asymmetries that result in mass for all of them versus the CSM. There must be three axes of symmetry in the asymmetrical arrangement of tiles mentioned earlier that corresponds to the shape of the manifold lobes.

The definition of the relative sizes of the asymmetries may or may not be the same across leptons and quarks. Experimental data may not allow to find out as only an "integrated" value of the various manifolds curvatures can be obtained through the measurement of their mass. But since we must have the same monadic spaces for matter, radiation and space, the asymmetries must be somehow related among the different arrangements. Also, it comes out experimentally that only the least asymmetries are stable (in fact, due to their low mass, neutrinos of more than one family are stable, unlike electrons and quarks). Such data may be able to give a hint on the parameters that fix the monadic elements characteristics.

The two flavors of quarks and leptons per family will be explained by examining the various "reactions" transforming the particles from one kind to another. Beta decay reactions (seen as "weak interactions" or "weak fields" in the Standard Model) connect the two different flavors of quarks and leptons within a family. For example,

$$\begin{aligned} u &\rightarrow d + e^{+} + \nu_e \\ d &\rightarrow u + e^{-} + \nu^{*}_{e} \end{aligned} \tag{5.3}$$

where u = up quark and d = down quark (the neutron is a "ddu" triplet of quarks and the proton is a "uud" triplet), "e^-"= electron, "e^+"= positron, "ν_e"= neutrino, "ν^*_e"= anti-neutrino, tells me that electrons and neutrinos (leptons) result from a partial decomposition of the sets of wheels making up the quarks resulting in their change of flavor.

An electron results from two of a "down" quark sets of wheels while an anti-neutrino comes out of the third. Neutrinos thus can relate for their gear with both photons and gluons, with sometimes a change of neutrino family through reorientation of the neutrino single space manifold versus the CSM via some gluon interaction.

The existence of the neutrino and electron as "complementary sets of wheels" leads to an understanding of why there are two flavors of quarks and leptons for each family. For example, up and down quarks have respectively +2/3 charge and -1/3 charge for their relations with photons, and thus unequal sets of wheels: The up quark has two "antimatter" sets of wheels like the positron and one "matter" set. The down quark has two antimatter sets, each like an electron anti-neutrino, and one matter set. The asymmetry above leads also to the anti-quarks where the wheel configurations are reversed versus the CSM. So quarks having 6 lobes split between the matter and antimatter "side" of this CSM, there must be two different ways to "peel" them into leptons, one with 2 sets of wheels and one with 1 set, thus breaking the equality of flavor masses for both quarks and leptons.

8. The relations ("reactions") between flavors

Elementary particles are known to be stable or have a finite "lifetime." The Standard Model has three families (six flavors) of such particles both in leptons and quarks with only one stable family, the one with the smallest masses (except for neutrinos). For example, within the leptons the electron has two *heavier* relatives, the muon and the tauon, both unstable, distiguishing themselves from the electron only by their much heavier mass. Where does this unstability come from?

A formal description of the process has been developed as part of the Standard Model using the concept of "weak interactions" defining a "weak" field. Even though certain experimental data can be deduced through this formalism, it does not make sense when trying to make a picture of what is really going on. When particles are thought as space manifolds, relating different manifold structures via a separate field is meaningless, especially one with very massive bosons as then the field has no spatial extent. Granted, the formalism itself may make sense, but this is not enough to produce a consistent and valid conceptualization. What the "weak" field concept really does is demonstrate that there are definite relationships within a family of quark flavors and lepton flavors structures, and codifies these relationships via field bosons W^+, W^-, Z^0 and photons coming out of a postulated SU(2) symmetry between flavors of particles. But these relationships do not have the postulated symmetries since masses of flavors within a family can be very different.

This "mass discrepancy" has been obviated by postulating a new field, the Higgs field, a hypothesis which is not so far substantiated by experimental data and about which theoretical inconsistencies are known to exist.[62] I shall add that the "symmetry breaking of the vacuum" necessary for this last hypothesis is fundamentally (physically) inconsistent with the notion that space does not exist on its own (Section III). Such a field could only be envisioned as a formalism like the weak field entities above if it intimately included somehow the content manifolds construction process out of the CSM as it may happen in "sink holes" (see later and Section VI), which of course the Higgs theory cannot cover. Space is not a separate entity with its own symmetry to break,[63] *and thus a Higgs field cannot exist*. This last conclusion has yet to be denied or confirmed experimentally.[64] Such an experiment will be as decisive for the nature of our space and time as the Michelson-Morley one of over a century ago that denied the existence of an "ether."

Finally, reactions involving more than one family of particles (quarks or leptons) have been thought as involving "weak" fields because non-conservation of parity is involved,[65] but this can be explained also from the monadic space origin of families and flavors as I describe here. "Intermediate vector bosons" can be then seen as an artificial concept that refers to the process of decomposition of the manifolds, either spontaneous or induced, which has a very short existence and almost no spatial dynamics (in the CSM).

9. The "lifetime" of manifolds

Within the monadic spaces concept, since the structure of the particle manifold tiles is dynamical, it may be that for certain ratios of pentagons vs. hexagons, the pentagons have a certain probability to abut each other and find it impossible to continue forming a complete structure after a certain evolution versus the CSM and the structure "rips apart" into photons, electron and neutrino. A particle manifold being a superposition of all the possible arrangements of its tiles, its lifetime has a probabilistic character when seen from the CSM.

I could ask then what happens to the other realities of that manifold after the "decay" at one location of the CSM. The answer would involve a key understanding of what a multiple reality of an entire monadic space manifold is versus another one in a different set of 3-Ds. The realities of the manifold monadic elements exist throughout the transition, together with their multiple connections to other manifolds in separate 3-Ds. They just get reconfigured into several manifolds, each with initial relations among themselves and with the CSM, and all with their various overall realities. This situation is in fact similar to the "state" of an atom as it experiences a transition between electronic configurations. The "state" of a quantum represents the relational configuration of all its realities. A transition is a change of this configuration, either "induced" (via external relation with other particles) or "spontaneous" (via its internal evolution).

The above addresses "spontaneous decays" of "elementary" quanta. As I discussed earlier content monadic relations are between sets of 3-D's such as electron-photon relations. When massive quanta come together this is the opportunity for "induced reactions" via the other 3D manifolds they connect to. Then monadic relations within the same 3-D come indirectly into effect and the manifolds get reconfigured according to specific rules, which can be formalized through the weak field intermediate vector bosons of the Standard Model picture as I addressed above.

E. The features of the common space manifold

1. The origin of gravitation

The *h/m* ratio discussed earlier reflects the curvature of the particle manifold. So the existence of non-hexagons among all the hexagons produces this curvature, and I will infer the same for the CSM since it is made out of such "tiles" (Fig. 7). Massive particles emit and absorb non-hexagonal tiles in a statistical Poisson process fashion thus creating a variable density of this type of tiles in the CSM. The density of non-hexagons *within a space and time reference defined by the bound spaces of localized quanta* then reflects the curvature of the CSM, thus gravitation.

In that picture, *Einstein/Galileo's Principle of Equivalence between gravitation and inertial mass corresponds to the necessity for the total number of non-hexagonal tiles in the CSM (gravitation) and in the monadic space manifolds (inertia) to be equal.*

2. Gravitation vs. quanta

There is no defined orientation of the content manifolds versus the CSM as they have only one monadic set of relations in common with it, there are no relative "set of wheels" rotations. This kind of relation between space manifolds is then "phaseless" and cannot define quanta. *Gravitation is thus not a quantized phenomenon*. The monadic elements of space, matter and radiation are *not* gravitons. They do not form "quanta of energy," they are only elements that can form quanta.

This kind of relation I identify with gravitation can be then seen as a tensorial field in our 3-D (curvature-like), while single vectorial (two-component) and multiple-vectorial (three-component) fields correspond to electromagnetic and strong forces. *These two last kinds of monadic relations between spaces occurring in the two other 3-D's, which I call matter/radiation relations, define quanta through the phases they maintain between their various realities using their multiple lobe interfaces* (as they have been visualized earlier).

3. Resolving Feynman's problem #1

But how can non-massive particles be affected by gravitation since their space manifolds must be made out of "tiles" for which no asymmetry can exist? Simply, this is because they are "attached" to the CSM, which is the common "bond" between all quanta, and thus must follow its curvature. This is the constructive reason for Mach's Principle[66] and the answer to the problem about factoring in the makeup of space that was raised within the view by Feynman identified in Section IV.

4. The gravitational constant

The gravitational constant reflects how much of an effect a massive quantum can have on the CSM, thus how relatively "diluted" the CSM is in asymmetries within its monadic elements. While matter and radiation manifolds have an infinitude of realities (connections with the CSM), the CSM has only one reality, being the reference reality for all of them as seen earlier. So a massive quantum can have its realities separated versus our space only as long as it can "lend" its monadic relations to the CSM to contribute to its construction (Fig. 7). The energy-time uncertainty comes from this lending ability (tied to *h*). The CSM gets a much smaller *local curvature* than the corresponding curvature of a "lending" electron space manifold because of the number of *symmetrical* monadic space manifolds contributing to the CSM. This can also be seen as the CSM limited ability to "warp." Thus *the gravitational constant has to represent the density of matter manifolds versus radiation manifolds connections with the CSM (thereby completing the definition of the scale of our reality). The gravitational constant must be then related to the relative size of matter and radiation monadic space manifolds, i.e. to the Planck constant h, to the fine structure constant and to the mass of the stable leptons.* I do not have the formalism to obtain this relation, but there may be an experimental way to find it as I describe now.

5. A potential dual-layer CSM

When the multiple realities of an electron can be *in two states* (two different spreads of realities) each tied to a spatial configuration of a sufficiently large number of localized quanta (atoms), and many of such electron-set of atoms arrangements (molecules) exist in a rather small area of the CSM, the set of localized quanta may find a more stable arrangement by connecting to each other through two parallel layers of the CSM that they would create by splitting their realities (Fig. 10). This arrangement would be favored because the set of localized quanta contains separate spaces (originating from the strong forces) with *a large inertia as a whole which would take more energy to move than the energy corresponding to the amount of monadic relations (photon exchanges) needed to create a space manifold connecting the two layers of the CSM*. Then the electrons and their photons exchanged in-between within the affected area would evolve as a whole monadic spaces system (coherent quantum) creating its own CSM separate from our reality, a space manifold I shall call "inertial" as a reminder of its origin. This arrangement would not be limited in time since it would not involve lending realities from a quantum system to the CSM, although it would require energy to maintain due to the photonic losses at the edges of the area.

The study of a system effecting the above arrangement and the energy it needs should give a way to tell what amount of radiation it takes to produce a space manifold like the CSM and relate it to the gravitational constant knowing the number of electrons involved. We would then get more information on the makeup of electronic monadic space manifolds relatively to radiation manifolds. A separate study will examine potential ways to obtain such systems.

6. A potential space-matter conversion process

The dilution of matter connections in the CSM must have a range of *stable concentrations* because, *once the concentration of non-hexagonal tiles becomes high enough to correspond to the concentration of a massive (asymmetric) monadic space manifold, a piece of the CSM would have to become a massive particle due to the corresponding curvature in the CSM.* Part of the CSM would then disappear and gravitation would be reduced. Under enormous gravitational fields such as in the formation of potential black holes, space would naturally "curl up" into massive particles which would be subsequently ejected by the sudden reduction in local gravitation. This process would be the origin of the very high energy *particle* beams observed as emitted by quasars and objects that are believed now to be rotating black holes. This subject will be examined further in Section VI.

Through this conversion process, an "uncomputable"[67] infinitely self-referential process (for which of course I don't have the formalism) would be performed and the "constants of Nature" recomputed. The CSM being the set of connections of the monadic space manifolds, i. e. the content of space, there is no way in this picture to envision a beginning or an end to such an evolution.

F. The creation of a non-local time

1. Feynman's last problem

The last problem identified in the approach by Feynman in Section IV was that the process total time was not relationally defined. The resolution is now at hand: Due to the existence of localized quanta, the various instantiations of a monadic space manifold making up a "quantum of energy" can relocate relatively to these localized quanta. But then the quantities identified in Physics have to be redefined.

2. Position and energy

Position is the configuration of the quanta realities *across the CSM relative to localized quanta realities*.

As identified earlier, the number of realities of a massive quantum is equated to the classical concept of *energy* for the quantum. This number of realities is the sum of the duplicated realities (1) from relations with virtual photons from localized quanta, and (2) from the motion reversals due to the mass of the particle. There is then both a spatial spread and a time spread of these realities.

For non-massive quanta, their "frequency" and "momentum" *within a given space and time reference* can be defined versus *localized quanta*. Since a monadic space manifold has a fixed number of monadic spaces, the energy must be then coming in multiples of h, $E = h\nu$. A photon has an undetermined proper time (it has no defined time) while its energy is fixed, that is, *its realities have no spread in time*.

3. Momentum

The meaning behind the *momentum* of a massive quantum can be understood through this energy picture and the concept of localized quanta. More realities available for the quantum and "quicker the (relative) travel" between localized quanta will occur since more interactions with virtual photons from nuclei (localized quanta) will be possible through a higher density of paths. Section VII will provide examples of these collective "travels" of realities. Momentum is then the configuration *across the particle proper time realities relative to the same localized quanta realities*. Not existing through the same set of realities position and momentum cannot be fully defined together, leading to Heisenberg's uncertainty principle.

The energy/momentum tensor of Relativity represents two complementary sets of realities, one being the spatial configuration of quanta realities, corresponding to Einstein's relation $E= mc^2$, the other their proper time configuration, corresponding to the momentum, thus Heisenberg's uncertainty in the determination of time versus energy is then a statement about the complementarity of space and time to define an evolution. Einstein's energy-mass relation does not represent an equivalence but a correspondence in the spatial number of monadic realities with the amount of asymmetry of the monadic space manifold, i.e. its mass. *So Einstein's well-known formula in fact needs Everett's multiple-reality concept in order to be explained!*

The *speed* concept for a "particle" has no meaning within the monadic space picture as it would require both a fixed connection separation in the CSM and a fixed time evolution, i. e. a single reality.

4. Observable and virtual quanta

Non-localized massive quanta have a *position* and a *momentum relative to localized quanta*. "Observable" quanta are *emitted (released)* by a localized quantum and *absorbed (captured)* by another localized quantum, thus changing the location where their energy can be found.

"Virtual" quanta are emitted and absorbed by the same quantum, either a localized quantum or a non-localized massive quantum such as an electron in travel between localized quanta. No energy is relocated via this process (thus its misleading "virtual" name, as it is as "real" as the other processes - this term was invented within Bohr's philosophy picturing the quantum world as a *dream* of some sort).

5. The computation of a non-local time

Our reality is constantly computing its evolution at the sub-nuclear, nuclear and atomic levels, and all the relational possibilities are being explored in parallel. The proper time of each quantum varies across its realities wherever they connect to the CSM. For each Feynman's path of a massive particle in the CSM there must be an infinitude of paths each with a different particle proper time progression. For example, a reality may enter an atom nucleus, thereby experience a large gravitational field changing its time versus its other realities.

A selection among the realities across the quanta is done to pick which realities for each quantum fit Lorentz transformations for their momentum as well as which realities fit Einstein/Galileo's Principle of Gravitation-Inertia Equivalence for their "acceleration," i.e. change of momentum, such that an overall consistent and non-local "*spacetime" across localized quanta* can be defined, with time only then becoming a coordinate complementing space by getting a full determination. The selection is accomplished through the fact that at a given spatial location the realities from other quanta exist, and thus the elements of "space" exist, only *when* their monadic computation is being performed. *Classical time is thus a product of the monadic relations between realities of the quanta across their proper times*. Today's Quantum Theory cannot connect to gravitation because it ignores the inherent non-permanence of "space" and the multiple times of the quantum realities, both features being inherent to the true quantum (monadic spaces) evolution process.

The multiple definitions in time are resolved (the "undeterminacies" are lifted, in the present quantum theory statistical approach understanding) by the necessities coming from the various kinds of monadic spaces relations, necessities that determine time at each CSM location: The localized quanta realities average time definitions corresponding to the strong force kind of monadic relations must match the definitions from the electromagnetic relations and from the tensorial relations corresponding to gravitation in the CSM. A "sufficient" number (understood as a measure for a continuum in the extended sense of the term as discussed in Section III) of quantum paths is involved, which dictates at what scale *classical time* (with local times consistently defined across the CSM) becomes fully defined.

In order to have paths with different times that nevertheless come together to match localized quanta, the paths must contain individual accelerations through the tensorial monadic relations that effect gravitation. Quantum Theory's wave function is computable only because this formalism (1) neglects these tensorial monadic relations (acceleration consistencies requirements) and (2) gives up on completely predicting the outcome of a process by treating all the realities of the quantum in a statistical fashion. Then we have equations such as Dirac's that contain only the *momentum* consistencies requirements of Special Relativity through the use of a Hamiltonian formulation that inherently assumes the proper times of all the quantum realities are the same. The uncomputability of the path selection process is placed in the artificial "wave function collapse (or reduction)" under the form of a *non-deterministic process*. The monadic spaces approach instead portrays the quantum world (and thus our reality) as deterministic, as well as classically uncomputable[68], with an unseparability aspect that provides both the generation of a space and the non-locality of the quantum.

6. "Extended Computation"

The "undeterminacies resolutions" (in the present quantum theory statistical views) are uncomputable processes in general within the usual definition (discrete mathematics) of computability because of two independent reasons, the computation (1) is uncountably infinite parallel among quantum paths across positions, and (2) occurs across an infinite set of proper times evolutions (with possibly closed time-like curves[69]). I shall use the term "*extended computation*" for such processes.

The term "computation" is used on the basis a step process exists (Section IV). The fact it then involves discrete features, even if infinite, does not change the identification as a computation. Algorithms can exist only for *distinct* sets of elements. Here there are "rules of deduction" (maybe in the sense of cellular automata) which may be infinite in numbers. What are the inputs and the results of such a computation? The computation in effect "processes" features in the set of monadic spaces that can be "distinguished" even though each element is undistinguishable. The result of the computation is the "topological" configuration after each step. Of course, in order to utilize such a computation the formalism of a new topology corresponding to the envisioned structured continuum needs to be developed (Section III) and devices performing it will have to be identified. A separate study will examine potential devices that may be obtained from Nature's own classically uncomputable search.

7. Irreversibility

Another question related to the differentiation process discussed here is about the origin of the "arrow of time." Where does the irreversibility of the flow of time come from? It has been a famous philosophical wonder since classical Statistical Mechanics was established (or before) and is still being wondered about (Davies, 1996; Coveney and Highfield, 1991) through the present Quantum Theory as all the laws of Physics are reversible in time. In the classical outlook of the world, the irreversibility comes from the statistics of large sets. In the monadic spaces understanding it is a fundamental feature. Besides being present in the very nature of the monads as "deductions from premises," the arrow of time is also present in the evolution of the quantum realities not only in the localizations that a wave function collapse would sometimes represent but in the monadic spaces evolution itself. Schroedinger's equation is reversible in time because it is a statistical formalism. The selection of a localization for a quantum defines where its energy will be located, and is not covered by the present quantum theory formalism, which assumes this selection contains all the irreversibility of the evolution process. Within the monadic spaces picture, all evolutions are extended computations and are irreversible since effected by monadic relations even though deterministic.

Separately, as I shall discuss in Section VI, the CSM contains monadic relations that identify a *statistical unbalance* between sources and sinks of space. Thus all the content manifolds, through their connection with the CSM, are inherently including the arrow of time. Tiny *time reversal asymmetries* will then show up in certain particles evolutions when observed from the classical world (where they ought to be time reversal symmetrical since seen through a statistical process from that world) simply due to their connection with the CSM. Roger Penrose's opinion[70] is that the arrow of time comes from the presence of singularities in "spacetime" but I am not aware of a formalism on that matter (the picture drawn by Relativity does not identify time as flowing differently toward past or future, being merely a coordinate). This phenomenon is explained here through monadic spaces by replacing singularities with space sinks (sink holes) and sources (stars and other matter-emitting astronomical objects), which in turn act on the time flow at a specific location in the CSM through the resulting unbalance of the local "tapestry" of the tiles set making up the CSM (Fig. 7). The General Relativity concept of spacetime is thus incomplete even on a classical level as time then contains an asymmetry due to the content of space being generated and eliminated at specific locations of the CSM, a process variable with time itself and affecting the local evolution of the CSM everywhere. Time as a coordinate is only an approximation, even classically.

G. Interpreting the concepts of Quantum Theory

1. Measurements

Within this picture I can define a "measurement,"[71] the concept described in conventional quantum mechanics (von Neumann's), as *a determination of the non-local configuration of the realities of a quantum* ***versus localized quanta****, which is then called a "state" of the quantum*, something that Schroedinger's equation tells us (via the nature of its Hamiltonian) is really a dynamical energy configuration (and thus matches the advanced equivalence of "energy" with the number of monadic space manifolds realities).

2. Chance

"Chance" (randomness) in the classical world as described through the formalism of the quantum wave function theory is *a result of an uncomputable but deterministic choice of the quantum multiple realities configuration, its "state," while the corresponding monadic spaces evolution is itself fundamentally deterministic*.

3. The "zero-point energy"

As Einstein said, there is no such thing as space without field. He was referring to the zero-point energy that has been found necessary to explain phenomena such as the Lamb shift and formalized via QED.[30] This shift has been explained by Feynman as the result of "emission into and re-absorption from the vacuum" of virtual photons, of course not knowing what the "vacuum" is made of. The term "virtual" is used in Feynman diagrams (Mattuck, 1992) to represent processes that may not conserve energy or even violate the Pauli Exclusion Principle. So in Quantum Theory they are "quasi-physical" processes. Such are at the origin of the dream-like physics that has been based solely on formalism without attempting to find a meaningful explanation of what is really going on. But a mathematical explanation is no explanation at all. It happens that the formalism gives results fitting experiments, that's all. So in present theory, due to the absence of a connection between the content manifolds (the quantum objects) and the CSM, there are content manifolds that appear and disappear in the calculations without leaving a trace. This is of course a symptom of the incompleteness of the theory, nothing more mysterious. I could say also that the real process behind the formalism is uncomputable, being an evolution of monadic space manifolds, and so the job of the formalism is to take the important features and express them so calculations can be made. But important features are being missed that way. All the physics is not there, and a separate study will attempt to show some of the key missing parts, all tied to how a CSM is built out of content manifolds connections, observable or not. The zero-point energy comes from the unobservable part.

4. Classicality and quantum decoherence

Quantum Theory as defined in the 1920s was an attempt to describe the quantum through a world that has lost its multiple reality character, where localized events replace the non-local aspect of multiple realities where everything goes at the speed of light and has individually inherently no time. Individuality and separability are the main characters of the classical world. Non-locality and superposition of pluralities are the main characters of the quantum and monadic spaces. The substitution of characters in the "transition to the classical world" happens at large in our reality and in particular through a "measurement." The present Decoherence Theory (Zurek, 1993; Zeh, 1996) covers this "transition" utilizing conventional quantum theory through its "density matrix" formalism, itself an adaptation of classical Statistical Mechanics. It identifies the process as computable since the formalism used is part of the wave function formalism, but it is of course uncomputable within the monadic spaces picture.

The monadic spaces picture includes the CSM makeup. It sees this transition as a process of localization of a set of multiple realities defining a *non-local time*, and *it occurs as a result of the impossibility to maintain all the various realities of interfacing localized quanta within the single reference reality of the CSM*. If there was a way to eliminate the localized quanta then there would not be a decoherence. The dual layer CSM would provide a way and thus lead to large-scale quantum phenomena.

For Zurek the transition always involves the definition of a "record" that is unchanging with time, which can be equated to a "memory" when a brain memory created through our thought process is used as a metaphor. The classical world is then the set of memories from the past quantum evolution, and decoherence is the selection of these memories.

As a special case where decoherence fails, it has been shown via the Schroedinger ion experiment that an ion can be in two places at the same time (up to 80 nanometers distance - See Monroe *et al.*, 1996), thereby giving an experimental evidence of the multiple realities *including localized quanta* making up our reality, as Everett envisioned. Beyond Everett's vision of the quantum (the content of space), with the dual-layer CSM discussed earlier there would be also ways to extend the above experiment to many atoms (in molecular arrangements) that would then collectively select special structural arrangements for the CSM in their region of the classical world. A separate study will review configurations that may display such arrangements.

5. The wave function

Everett's interpretation of quantum theory was an attempt to describe the meaning of multiple reality through Schroedinger's wave function formalism (Section III). It failed in the sense that the wave function concept is tied to a measuring apparatus, a classical being. Non-separability of the quantum shows that the wave function notion is fundamentally incomplete,[72] and unsalvageable if we want to go beyond it in order to make further progress. The new formalism must cover all the various ways monadic spaces multiple realities are generated and evolve, including the crucial asymmetries within the CSM and its possible structural arrangements, as well as how these multiple realities and arrangements get selected, thereby *creating* the classical world, i. e. the "memories" Zurek describes.

H. The price paid for dealing with "uncomputability"

Can a classically uncomputable process be treated mathematically without leaving out fundamental features? I have shown here that, at least, a few basic conclusions can be reached through imagination reined in by logic (and only very partially helped by figures!). Further insights will require a sharpening of our mathematical tools in order to handle monadic spaces. The uncomputability of the monadic spaces evolution *and the corresponding present lack of formalism* prevent me from deriving at this point any data on relative masses of particles or constants of Nature. I can only predict, as I did, from logical relations in the monadic space picture certain facts that have otherwise no foundation in the Standard Model, such as the fact all neutrinos must have a mass, or features that have been taken for granted in the Standard Model but have so far no experimental backup such as glueballs and Higgs field, which I find non-existent through the monadic spaces picture.

This kind of preliminary *creative* logical process that I have followed seems to be a necessity if uncomputable features (in our present mathematical outlook) of reality are to be addressed. This is the eventuality that was not considered possible by the logical positivists (Section II). The looked-for formalism may include a cosmological continuity equation (Section VI) and related formulae describing the birth/death of massive particles (confinement/freedom "reactions") as mentioned earlier. Constraints inherent to the monadic spaces manifolds produced in "sink holes" (Section VI) would define their needed asymmetries and thus their masses. Being the only situation where the CSM de-facto breaks down into content manifolds, all the "constants of Nature" would also have to relationally "size" each other in the process (of course against the speed of light, which is the relational base of the system).

In relation with the matter of uncomputability, my description may also leave the feeling that monadic spaces are discrete in the present mathematical definition of "discrete." As I mentioned in Section III, I deal with "discrete volume frames" uncountably infinitely stacked on top of each other, a "structured" continuum. Discrete volume frames are non-local undistiguishable entities made of countably infinite parts that cannot be picked alone in the stack. In present mathematics, "discrete" assumes "distinguishable," and "continuous" assumes a "local neighborhood." As such, the terminology of current mathematics, which originally came from Classical Mechanics, does not apply here.

I. Summary and outlook for next sections

Present-days Quantum Physics sees any quantum process as computable with an *unpredictable* specific measurement result, this result being merely part of a catalog called the wave function. Whether Quantum Mechanics is complete as a theory in light of this very feature was wondered about by both Einstein and Schroedinger.[73] When the monadic spaces picture is considered, our reality is deterministic, and non-determinism is only artificially created through the present quantum theory formalism by treating the monadic spaces evolution as a statistical process. This formalism then cannot cover many fundamental features of our reality that are envisioned through the monadic spaces concept, such as the physical meaning behind "wave function collapses" and the origin of space from interplay within its content. This hypothesis can be experimentally supported through the non-existence of a Higgs field, a field otherwise predicted by the present "electroweak" quantum field theory by seeing space as an arena. The existence of only three families of massive particles can also prove in the long run that our reality is relationally defined as the monadic spaces hypothesis describes. A corroborating experimental result will be that all neutrinos must have masses. (The monadic space picture comes up with that fact while the Standard Model cannot.)

The monadic spaces picture may look to be connected somehow to the theory of Superstrings[74] (e.g. a 10-D spacetime is found necessary in that theory, and particle manifolds intersections with the CSM may be seen as strings), but the nature of monadic spaces relations is very different from strings relations, notably in the origin of gravitation as no string can possibly be involved in that aspect of the relations, quanta being not formed. The formalism of strings thereby misses the inherent ordinary space and time definitions coming with monadic spaces, and thus cannot connect the quantum with gravitation.

In the monadic spaces picture, our reality is constantly self-generating, and ordinary space must be made out of the same "stuff" as matter and radiation, that is, relations between monadic spaces. Spatial definitions and time only appear as computed quantities out of these relations, not as pre-defined "coordinates" as Einstein and Minkowski saw it. Our space then cannot expand from a point or shrink to a point as this would deny the very existence of the monadic relations interplay, and thus reality. A Genesis-type of universe, the Big Bang universe of today's Science, does not fit within such a description. Next Section will discuss the possible experimental confirmation of such a conclusion.

VI. THE CASE OF THE MISSING EQUATION

The problem of the "cosmological constant" has preoccupied me for a number of years. This started from an article in Scientific American[75] dating from 10 years ago describing the consequences of Particle Physics standard model of leptons and baryons/hadrons with their respective bosons (photons, gluons) for the energy tensor of General Relativity. The article pointed out that this model implies a very large cosmological constant while a constant amounting to zero for all practical purposes is observed. This problem is still unsolved by today's Physics. After coming to my conclusions about monadic spaces as I described in previous sections telling me that space was not an arena, and that most of it results from the electromagnetic field, I went to review the origins of Einstein's equation to see how the curvature of space is dictated by the energy tensor of matter/radiation in the framework of General Relativity.

A. The closed universe hypothesis

It was stated in Einstein's original paper[76] that he was looking for an equation modelled on the *Poisson equation* of *Newtonian Theory* (which has a counterpart in *Electrostatics*), where the Laplacian of the field potential equals the density of matter (charges for electrostatics). The field potential was then equated by Einstein to the curvature tensor of spacetime, and the matter density was equated to the matter/radiation energy tensor giving the well-known tensorial equation of gravitation. At that point Einstein should have realized, if he wanted to be accurate with his correspondence absolute space/relative space via Poisson equation, that his system was incompletely defined because the equation he obtained signified that the fabric of space is dynamic, requiring thereby to define a source for that space. In other words he should have thought the Poisson equation as *coming from Electrostatics instead of the Newtonian Theory*. The confusion came from the fact that *he was assuming a* ***closed*** *static system in the first place*.[77] With an open system a correspondence with *Electrodynamics* (or *Hydrodynamics*) would have been necessary, including the requirement for a *continuity equation*.[78] This closed system hypothesis led him (unknowingly!) to postulate that such an equation was not required to describe the evolution of space. This postulate was chosen without a physical base at all, just as "obvious" (since the system is a *universe* after all!), but recently acquired experimental knowledge in Cosmology goes against it, as I describe later on, and this knowledge fits previous discoveries in Particle Physics postdating Einstein's lifetime.

B. Sources and sinks of space

Einstein had indeed a very good excuse for the confusion: He did not live long enough to learn the crucial facts. He was in fact looking for the unity between gravitation and electromagnetism for a long time. This search was not to find a "unified theory between fields" as later identified, but *to find the origin* *of space*. Indeed, back in the 1920s Einstein was looking for a tensor providing the correspondence between electro-magnetism and space through his old dealings with Lorentz's picture of the electron. He could not have known that matter has essentially two forms: one that is *confined* (the quarks/gluons) and one that is *free* (leptons/photons). Both contribute to gravitation (i.e. the curvature of space) but one (the free kind - electromagnetism!) is the main source of the *volume* or *extent* of space. In that picture *space is an open system and dynamic*. For example stars produce photons from confined matter and thus are *sources of space*. Then, as the Poisson equation does not fully determine the electromagnetic field in an open system, Einstein's equation does not fully determine the gravitational field. Also, contrary to what is pictured by that equation, time must have a special role compared to spatial coordinates in order to reflect the open character of the system.

Einstein could not know that space has sources. Today's Physics does not have his excuse. The present incomplete "effective field theory" approach of Quantum Field Theory could be seen as what it is, only a formalism to cover experimental data (see Section V). The representation of sources could be then seen as not fitting in Einstein's theory. The fact that matter can transform from a confined to a free kind in stars is not being seen as a space generation process. If it was, only a small leap of the imagination would be needed to conclude that this process may reverse itself in large unseen accumulations of matter found possible through Einstein's closed system equation under the term of "black holes," which I will rather call "sink holes." Through the monadic spaces concept presented in Section V, sources and sinks of space are necessary as a result of the properties of monadic relations making up particles. A continuity equation is then required to complete the description of gravitation.

1. Sink holes vs. black holes

Sink holes would be quite different from the black holes studied by today's Astrophysics (Wald, 1984; Thorne, 1994). They would provide, through local gravitational collapse, transient conditions for free matter to become confined again through "condensation" of space as envisioned in Section V, thus producing violent bursts of particles by the consequent sudden spatial squeeze and gravitational release. The universe would then have no beginning or end, just changes (local and global) in the matter/radiation energy tensor and spacetime curvature, with the energy tensor at a given spacetime location itself being affected by spatial sources and sinks in the lightcone past of the location. It would truly be a relational universe in the monadic space concept sense.

2. A modifier of gravitation

The existence of sources and sinks of space could be seen as a "modifier" of gravitation, positive and negative. These effects would vary according to the net amount of space being generated or eliminated locally by a galaxy for example, this amount itself originating in the way matter can become free or confined, something unrelated to the origin of gravitation which is from the amount of matter present. But since such a phenomenon would affect the *density* of matter, it would be able to decrease the *local* effective gravity, i.e. without shining the sun would display more gravitation, or increase, i.e. a sink hole would increase the observed gravitation. In this last case the mass of the black holes of today's Astrophysics would have to be reduced (and most likely reduced to nothing!) from the presently assumed from observation because of the effect of disappearance of space through them, as being in reality sink holes.

3. The local aspect of space generation

Against the universal expansion (as a whole)[79] theory dating back to the astronomical observations by Hubble (1929), in the picture of space being built by its content, our galaxy would generate space through its stars, the “new” space *combining* itself with the background space away from the galaxy disk, and thereby producing a change of wavelength for any incoming radiation from faraway places (see Appendix A). Such a space generation would then *not* amount to an overall universe expansion, it would be only a physical effect connected to the space generated by our galaxy, a local source of space. The universal space would be a combination of all the spaces generated by its sources. Other locations would have instead sinks of space. As a potential example the center of our galaxy may have a sink hole. The algebraic sum of sources and this sink effects on space would have to be positive since there is an observed positive Hubble constant.

In that respect, the observed fact that galaxies have been found to rotate as part of a spherical or doughnut-shaped *whole* could be explained from the “space system” generated by the stars within the galaxies. This space system would displace the background space of the infinite universe. The sink hole at the disk center would give an overall doughnut instead of a sphere through “sucking” the space around it. This rotation as a whole is explained in Astrophysics through postulating “dark matter” above and under the galaxies disk. But dark matter is a ghost in Physics, as for now at least 15 years it has never been observed in Earth-bound experiments, and a lot of it is needed to give the effects observed. Peebles calls this discrepancy an “embarassment” for today’s Science (Peebles, 1998).

Also, recent observational results (see references in Appendix A) are interpreted as indicating that the overall universe would have a rate of expansion *increasing* with time, in the universal expansion picture mentioned above. In that picture the expansion is the result of a primordial “explosion,” the Big Bang, throwing matter away from itself. But then such an expansion could only decelerate with time, not accelerate. So, as a result of the new observations, today’s Astrophysics is obliged to advance the existence of a repulsive, antigravity-type force, a “dark energy” corresponding to *a nonzero cosmological constant* in order to explain this discrepancy. But no physical process is known to generate such a bizarre energy (with negative pressure!).

Appendix A reviews the experimental data that brought this problem, and finds that, through the hypothesis of space generation, what is observed merely reflects the age of our sun, a pretty simple physical effect to analyze indeed. As a matter of fact, an experimental support for the picture of space being built by its content could be found through the observations in question.

If Einstein’s theory was left alone a cosmological constant would be only a very imperfect way to represent a net surplus of local sources. The reason is that the effect of sources/sinks is bound to a local process, and the constant can only give a *universal unstable* static system. For that reason it was an arbitrary addition to Einstein’s equation. Einstein knew it (the adequacy of the cosmological constant was questioned very early on by Friedmann[80]) and cited this reason to drop it. There is still no reason for it. The problems above simply need the cosmological continuity equation for their resolution.

4. A bounded fractal process?

One consequence from a universe evolution with sources and sinks is its perpetual character: Once space has been generated in a “sufficient” amount, the sources are no longer dominant and a reduction of space amount is begun due to the gathering of masses by gravitation. Once the reduction of space amount is “sufficient,” generation turns again predominant. At some scale there *may* be an equilibrium between the amount of sources and sinks. This is one of the questions that a continuity equation would answer. In any case, the relatively slow pace of the process, the distances involved, the non-linear complexity of cosmic plasma effects, all conspire to preclude such a process from becoming stationary or cyclical. This is then a "non-stationary cosmological picture," very different from any artificially conceived "steady-state" one defined within a spacetime concept that does not include sinks and sources of space.

On an experimental line, the well-mapped *closer* portion of the visible universe looks to have a foam-like structure (fractal dimension 2), with giant voids and large-scale clusters of galaxies,[81] a structure that fits the source/sink picture through the space bubbles and voids created by a local unbalance between sources and sinks, while uniformity (fractal dimension 3) would be found at remote distances if there is a bound for the fractal range. The present controversy raging over the extent of this fractal scale will take many more surveys and recalculations to settle, if ever, as such a fractal nature, even if bounded, would go against the universal uniformity hypothesis[82] of General Relativity, which is the present "Cosmological Principle" or "Standard Model of Cosmology." A revised theory finding its support from new astronomical data (Appendix A) and other fields may give at last an out.

5. No singularities

Another consequence is that the process has no built-in dead-end such as a singularity at the center of black holes, or any other singularity such as the one needed in a process creating "wormholes." Einstein would like this idea, as he was against singularities in Nature.

C. Other experimental data with space generation interpretations

What are some of the other astronomical phenomena that can be accounted for or predicted by the approach followed by this study?

First, sink holes would involve electromagnetism through the picture of cosmic plasma (Alfven, 1981) in order to describe the particles ejection process. Existing black hole theory (Price and Thorne, 1988) tries to include cosmic plasma, but the magnitude and kind of jets observed remain unexplained.

Second, the observed cosmic microwave background radiation can find an explanation in the stochastic confluence of jets emitted by sink holes (galactic nuclei) acting as a radio fog[83] giving a near-perfect blackbody radiation in the microwave range.

Third, the observed cosmic gamma ray bursts (Glanz, 1997; Andersen, 1999; Castro-Tirado, 1999; Hjorth, 1999; Normile, 1999) may finally have an explanation as only large space squeezes may be able to generate such an amount of energy in bursts (cosmic plasma alone and rotating black holes even when absorbing neutron stars can't do it). Likewise quasars bursts of matter[84] in blobs may get a much better account.

D. The continuity equation

Going back to the cosmological constant, the question is then replaced by *how to generate a continuity equation for space from the Standard Model of Particle Physics.* The equation would need to express the generation or elimination of space with time as a given amount of leptons/photons corresponds to a specific amount of space. This matter/radiation would correspond to a certain volume coming from elementary particles monadic relations. The continuity equation would take care of the source/sink effect of such relations, and remove the need for a cosmological constant in Einstein's equation. The matter/space relation constant in the continuity equation then would have to reflect the *quantum zero-point energy* attached to the matter/radiation generated/absorbed by the sources/sinks. This energy would be coupled to the local matter/radiation energy tensor through confinement/freedom reaction formulae describing the *generation and elimination of matter/radiation* as discussed in Section V. These formulae would give a specific amount of space eliminated and generated for the corresponding matter/radiation, and thus the value of the matter/space relation constant. ***The quantum would be at last connected with gravitation***.

E. Conclusion

According to General Relativity gravitational fields come from the spacetime curvature generated by the content of space, itself considered as an arena. A universal spatial expansion was added to the General Relativity picture in 1929 on the basis of astronomical observations and within the theory's closed universe hypothesis.

When using the alternate hypothesis presented in this study that space is built by its content, spacetime curvature can be also affected by the infinite combination of space sources and sinks, the consideration of such leading to an *open universe*. In this alternate picture the Hubble constant would represent a net positive space generation rate out of our galaxy, not an overall expansion of the universe.

This theory would explain in a physical manner many experimental facts that go against the hypotheses of General Relativity. First, the universal expansion assumption part of the *closed universe hypothesis* is not helped by recent observations forcing the assumption of a bizarre "dark energy" on top of an earlier assumption of a ghostly dark matter. Both these assumptions have no physical support whatsoever. Second, the *uniform universe hypothesis* is not supported by a fractal layout of the universe which has been also recently tentatively identified.

The difficulties of both closed universe and uniform universe hypotheses can be addressed by the alternate theory. A lot of known facts can be explained through it and the gathering of new astronomical data (Appendix A) could justify it. However, knowing the controversies involved and the alternate explanations formulated in this field for so many years, its experimental support may still need additional help from other fields.

VII. QUANTUM PHYSICS, AN ALTERNATE PICTURE

In order to visualize further how quanta relate to each other and to our ordinary space manifold as sets of monadic spaces I will use a few examples of key experimental set-ups that were invented along the years of the 20th century marking our progress in discovering the non-local aspect of the quantum. Here is a list of such set-ups:

1. Differentiated localities: Davisson-Germer's electron diffraction (Davisson and Germer, 1927)
2. Differentiated directions: Stern-Gerlach's spin polarization (Gerlach and Stern, 1922)[85]
3. Einstein-Podolsky-Rosen (EPR) non-local quantum thought experiment (Einstein *et al.*, 1935) and Aspect's non-local photon (Aspect *et al.*, 1982)
4 Schroedinger's Cat thought experiment (Schroedinger, 1935) and the Schroedinger Cat ion duplication (Monroe *et al.*, 1996)[86]
5. Aharonov-Bohm's influence-at-a-distance (1950s)[87]
6. Kochen-Specker's (Kochen and Specker, 1967) and Penrose's contextuality thought experiments (1994)[88]
7. Wheeler's delayed choice thought experiment (Wheeler, 1978, 1994)
8. Neutron gravitation interferometry (1970s)[89]
9. Unruh-Davies's quantum acceleration (Davies, 1975; Unruh, 1976; Milonni, 1994)
10. Neutron diffraction (Zeilinger *et al.*, 1988)[90]
11. Quantum eraser (Scully *et al.*, 1991)[91]
12. Bennett's quantum state teleportation (Bennett *et al.*, 1993)

13. Elitzur-Vaidman's non-local counterfactual "null measurement" (Elitzur and Vaidman, 1993)

Each is provided with a reference for the reader to get a start on his/her own investigation. Five examples are taken from the list and analyzed below to show how they can be *intuitively* understood on a monadic space concept level. Kwiat pointed out (Taubes, 1996) that

"Everyone has some intuition about baseball and billiard balls, which is invaluable for engineering mechanical devices, but very few people have intuition about these quantum mechanical interference and information effects. And the only way to make anything useful with them is if we really do have that good intuition."

I must add, and strongly emphasize, that our present quantum mechanical formalism is not meant to lend itself to an intuitive understanding (as the logical positivist Bohr worked to ensure through the founders of Quantum Mechanics, in knowingly not providing understanding, only a formalism - see Section II), leading to "weird" and "voodoo-like" wonders that really need not be there, and are now in the way of our progress. Not only such wonders create a problem for understanding our reality behind the established formalism, and thus for putting the formalism to practical use, but they look to be a fundamental barrier against finding (or visualizing) new features.

A. Differentiated localities: 2-slit electron diffraction experiment

First, the 2-slit electron diffraction experiment is presented to discuss relations involving localizations around nuclear quanta. This is a thought experiment, idealized from the Davisson and Germer (1927) experiment with diffraction of electrons on a crystal.

An electron, a quantum emitted from an atom (i.e. a composite localized quantum), passing the slits in a 2-slit screen, even though its realities are no longer localized, will be forced to "land" on a specific atom of the screen. It cannot land on all of them and thus remain delocalized if the screen must perform its job as "marker." It could remain delocalized though if the screen was a conducting material, but here the localized quanta are not synchronized with each other as their electronic orbitals does not allow delocalizations of electrons. The electron thus selects which atom (and thus which localization) by interacting with the virtual photons from a single atom. The selection is made by the "instants" when such photons update as seen by every particle making up the superposition continuum (Section III).

A virtual photon from a nucleus follows an infinite number of parallel paths in different realities very much as the electron does. The various realities of a given virtual photon associated with a given nucleus will impart a bias for all the realities of the electron to get toward that nucleus, as well as will "imply" succeeding relations with another photon of the same nucleus because the updating is related in time for all the photons of that nucleus. At the end of the electron "travel" (read "chain of implications") all its realities will end up being around that nucleus, and thus the spatial relational symmetry between the electron and the screen atoms will be broken. The electron will become again a localized quantum of energy. During this process, if the electron realities interfere destructively the electron presence will not be seen by the screen atoms virtual photons, while in the constructive interference areas the virtual photons will have more chance to affect the electron travel.

I have just described an electromagnetic form of *localization change* ("travel") for a massive quantum, an electron manifold in its 3-D relating to virtual photon manifolds in their own 3-D, all connected to our ordinary space manifold (Section V).

REMARK.

- I have described above the physical meaning behind the "collapse of the wave function" in the von Neumann measurement theory of Quantum Mechanics.[92] The screen is the "measuring instrument." Unlike the parallel universes view expressed by Everett in his "Universal Wave Function" thesis (DeWitt and Graham, 1973) where there is no wave function collapse, in the multiple-reality monadic space view there are parallel evolutionary paths for quantum realities necessitated by the multiple possibilities for their monadic relations. With the existence of localized quanta, there are delocalization and localization processes for these quantum realities which can be identified in certain cases, as in the example above, with a wave function collapse, but not always, as I shall describe through the next experiments. It is a "natural" or "objective" process in the sense that there is no need for an "observation" or "measurement" by humans as conventional quantum mechanics understands (Wheeler and Zurek, 1983).

B. Differentiated directions: The Stern-Gerlach experiment

The collapse may not occur when differentiated localities are replaced by differentiated directions produced through a breakdown of the spatial directions symmetry within the monadic relations. This situation can be illustrated by the Stern-Gerlach experiment. A macroscopic magnetic field is created differentiating space orientations for the "outer" electron of an atom travelling across the magnet and interacting with its field virtual photons. According to Heisenberg's uncertainty principle, in such a situation the atom has enough energy for its travel to be considered as a classical trajectory. If the atom does not "crash" on the screen right after the magnet, it will be then surrounded by realities of the electron where the spin has a "polarization" according to the magnet field direction. A magnet further along in the atom trajectory may pick up another set of realities. And this can continue as long as the atom does not crash on one of the screens located after each magnet (after being deflected by the magnet according to the chosen spin reality) because the electron spin variable of the atom will not have its wave function collapsed throughout the entire process.

However, I know for certain that after the first magnet, if the atom has not crashed on the screen, it will definitely crash on the screen of the second magnet if that magnet is oriented the same way as the first and the screen after the second magnet is located in the path of the atom corresponding to the polarization effected by the first magnet. What has then been done is a "quantum state preparation"[93] in the sense that I know the reality chosen for the electron through the first magnet even though I have not measured it through recording and no collapse of the wave function has occurred. Einstein would say that there is an "element of reality" in the subsequent orientation of the spin of the atom (Einstein *et al*., 1935). This "knowledge" won't be finalized though until I actually record this reality with a crash of the atom on the second magnet screen. And then, if the second magnet has a field in a *perpendicular* direction to the first, the first selection of reality will be "cancelled" altogether. If the direction is not perpendicular there are "remains" of the old reality selection which will superpose to the new one.

Now how could that happen? In the second "selection of reality" the realities of the electron spin will either remain in the same direction configuration if the second magnet field direction is the same as the first magnet or will change if the field direction is different. But then the spin direction realities are merely "localized" in their direction by the synchronized oriented virtual photons of the successive fields very much as an electron presence is localized around a nucleus via its synchronized virtual photons in the 2-slit experiment. The various realities of the spin direction then can be grouped within a set of two arbitrarily chosen relatively perpendicular directions, and this grouping can be changed by a subsequent set of directions for the field.

I can only conclude that each direction of the field corresponds to a different reality selection of the electronic quantum through the quantum proper times synchronization with the oriented virtual photons of each magnet (a set of localized quanta). An independent set of realities can be defined (in the sense of independence of components or dimensions in linear algebra). There is thus a selection of reality done but no spin wave function collapse unless the atom crashes on the screen.

Through this experiment Everett's views of parallel realities become unworkable, as it is certainly difficult to discern here a meaningful branching of realities through an "observer" observation or a "cloning" of observers through an observation as Everett envisioned in his original paper. In Appendix B I lay out a set a rules which clarify the understanding one can obtain from Everett's views.

C. EPR non-locality and quantum teleportation

The selection of reality identified in the Stern-Gerlach experiment is a non-local feature for the quantum system under consideration, that is, once a reality is selected the quantum system will display the selection instantaneously throughout the common ("classical") reality. As Everett has put out (Everett, 1957), this common reality can be seen then as defining a "relative state" for the quantum realities through the use of an observing/interacting instrument. Such a feature was the subject of the 1935 EPR paper (Einstein *et al.*, 1935), thereby portraying quantum mechanics, as it was then defined, as incomplete since it did not identify the "elements of reality" that were non-locally selected by the classical instrument. Everett then attempted to complete quantum theory via his multiple-reality concept. I shall add that *this non-local feature of the quantum is related to the single reality character of the common monadic space manifold*, the same character that makes gravitation a non-quantum phenomenon (no "gravitons"), through the monadic spaces unseparability feature as described in Section V.

Now, because of this single-reality character, the selection of reality done through a classical instrument such as the Stern-Gerlach magnet, can be done also via a quantum system. If a quantum system A has its realities spatially split, as in the EPR thought experiment, at point X one set of realities A1 may have monadic relations with another quantum system B set of realities B1. Then instantaneously the realities B2 located at point Y interacting with A2 will be selected by the quantum system A, forming the complement (B2, A2) to the realities (A1, B1). Subsequently, if realities (A1, B1) are measured at point X by the classical instrument, the variables that defined the measurement at point X can be *classically communicated* (via ordinary radio links for example) to point Y so the measurement there then obtains the set (A1, B1). The state of the system B will have been then "teleported" (in a "telepathic" way as Einstein put out) from point X to point Y by the reality selection at point X by system A.

Such a feature then gives (Furuzawa *et al.*, 1998)[94] *a method of transfer for the states of a massive quantum at the speed of light* as a quantum is *undistinguishable* from another when their states are identical. Shimony showed (Bennett *et al.*, 1993) that information (a classical concept) still can't be transferred that way, but this deduction assumes the framework of conventional quantum mechanics where only the classical world exists and thus where only the classical world can "dream" of the quantum, not the other way around, as Bohr conveyed when the quantum mechanical framework was being established. The fact that the quantum system seems to "know" the status of its various realities still would not violate Einstein's classical causality as only the quantum system would "know." And then if the quantum system transfers this information to the classical world, it would not be taken by that world as information since it would be identified through the conventional *statistical* quantum theory as giving a random selection.

But Everett's multiple-reality viewpoint when combined with the monadic spaces concept may allow, as I shall describe in a separate study, to discern quantum systems that may exist with the ability to observe the classical world from *within their own space*. If the manifold of such space is physically extendable across spacelike points within the classical world, *the possibility for quantum systems to communicate information instantaneously to the classical world over spacelike distances would still be theoretically there*. Causality would not be violated because the quantum does not operate locally, in contrast with the classical world which has lost its unity (as I have discussed in Section V). In the monadic spaces picture the speed of light is the base for "individual" monadic relations (really for quanta since there is no such thing as individual monadic relations), not for the various realities of a set of relations, which form a *non-local whole*. It is then a limiting factor only when looking at quantum processes from the classical world as it is done in the teleportation experiment, and everywhere else in present quantum theory, and thus *may be only an artificial limitation fabricated by our present theories.*

D. A non-local "counterfactual" experiment

The evolution of a non-local set of monadic spaces realities constituting a quantum may give measurable effects that could be seen as bypassing somehow the lightcone causality limitations of Relativity. These non-local realities would correspond to the "discrete volume frames" making up the physical continuum envisioned in Section III, "unseparable" non-local entities that would be behind the non-local features of the quantum.

A simple non-local quantum system can be analyzed through an optical "null-measurement" interferometry experiment (similar results can be obtained with massive particles using a neutron interferometer - Krenn *et al.*, 1995).

1. The set-up

The theoretical set-up imagined by Vaidman et al.[95] utilizes a Mach-Zehnder interferometer (Fig. 11). As conventional quantum optics can describe, the amplitudes of the photon wave originally emitted from point source S and leading to detector D_2 *interfere* destructively, and therefore only detector D_1 can click. If we insert into path "I" an object absorbing light perfectly, this path is blocked, no interference occurs, and both detectors will click with equal *probability*. Thus if a *single* photon is sent into the interferometer and a click is detected in D_2, one knows for sure that an object is present in path "I" *without the photon having interacted with this object* (which is a counterfactual conclusion). Of course, it is also possible that the photon ends up absorbed by the object or detected in D_1 but nevertheless in 25% of all trials we will succeed in performing an *interaction-free measurement*, or so it seems.

2. The analysis

I now turn to the quantum multiple-reality description of the postulated set-up. There are seven possible interactions for the photon within this set-up: two detectors, two half-mirrors, two mirrors and one blocking object. I will assume that the blocking object can tell the observer of the set-up it has been hit by a photon through some *observable* action. It could be an object changing color, or a bomb that explodes, anything to indicate its *state* has changed (in a macroscopic sense). Half-mirrors atoms monadic relations with the photon realities delocalize the photon in two sets of realities, one where they are reflected and one where they pass through the mirror. Full mirrors interact with the photon realities by changing their reality wave vector direction.

I will now follow the photon realities[96] starting from source S and see what can happen to them on their ways to the detectors or the blocking object. If the object is not present (Fig. 12), we have *at first sight* four possible simultaneous routes, 1-1A, 1-1B, 2-2A, 2-2B. The photon realities split into routes 1 and 2 at half-mirror H_1, then split again into routes 1A, 1B, 2A, 2B after half-mirror H_2, towards detectors D_1 and D_2. At H_2 however, reality set 1 must merge (superpose) with reality set 2 since the photon realities remain synchronized as a result of the parallel orientation of the mirrors and identical length optical paths.

Then the top two coordinated choices of routes in Fig. 12, in which a single photon reality set would be observed at either detector D1 or D2, *cannot exist*. These choices would exist only if the sets of realities 1 and 2 were not *coherent*. The interaction at H_2 is said to be *coherent* because the phases of the photon wave function must be used in order to come up with the right outcome (otherwise the system is "decohered"). Furthermore, realities 1B and 2B being in opposite phase as a result of the mirrors reflection and refraction properties on the way to D_2, they cancel each other out in their superposition ("destructive interference"), and the set of realities 1B/2B also *cannot exist*. The presence of the photon is then spatially reinforced at detector D_1 to a probability unity in the only possible set of realities, 1A/2A.

Now, with the blocking object in the photon path "I" (Fig. 11), the photon realities starting from S will split at H_1 into two sets of realities with one following route 1 and the other being split again at H_2 following two routes 2-2A and 2-2B (Fig. 13). Each of the detectors D_1 and D_2 can then interact with only one of the realities 2A or 2B coming out of H_2 interaction with photon reality 2. No superposition of photon realities ("interference" by merging of realities) will occur after H_2 in this case since route 1 is blocked by the object. And since the two interactions, one at either detector D_1 or D_2 and one at the object, result from the same initial monadic relations at H_1, these interactions will be in the same monadic relations tree and thus "related." The observer of the set-up will see the object change state, *or* see D_1 or D_2 detect the photon, these events being mutually exclusive as a result of the photon monadic spaces realities localization.

The final monadic interactions between detector, object and the photon realities will occur separately in time since such interactions, ocurring with different atoms (localized quanta) are not synchronized. But once a photon reality set has had a monadic relation with an atom the quantum starts its localization process.

The observer will end up in one of 5 classical realities, the 5 cases of observation shown in Fig. 12 (object not present), - case 1- by observing reality set 1A/2A (detector D_1), and in Fig. 13 - cases 2 and 3 - by observing reality set 1 (the object) in either of two realities routing possibilities, or - case 4 - reality set 2A (detector D_1) or - case 5 - reality set 2B (detector D_2) observation. Only the last case ensures one of the photon realities did find the object without changing the object's state within the end reality of the observer.

In case 5 above, the realities reaching the blocking object (it is the first set of atoms reached by the realities of the photon) fail to synchronize with the virtual photons of the atoms of the object and thus *cease to exist by the monadic relations chains ending there*. But since an uncountable infinite set of these realities exists elsewhere, the other realities set going towards D_2 becomes the entire quantum, localized in that trajectory (an infinite set has the same cardinality as its parts).

This process can be identified with the "wave function collapse" of conventional quantum mechanics *provided this collapse is seen as occurring at the detector*, giving then the "counterfactual" effect perceived through that theory. Conventional quantum theory expects any wave function collapse to be tied to an *observation through a classical instrument*, a process perceived as local and instantaneous. Within the monadic spaces concept such a process is non-local and not tied to an observation at all. Everett (1957) proposed a formulation of Quantum Theory which did not presuppose a wave function collapse. I review this formulation in Appendix B to clarify the meaning of "observation" considered in that situation.

REMARKS.

- The "quantum Zeno effect" referred by Kwiat *et al*. (1995) allows bringing the probability of "detecting" the bomb without exploding it theoretically to 1. This effect can be readily explained *without quantum mechanics formalism* via the quantum multiple reality view: By increasing the number of interactions with the half-mirrors in the null-measurement interferometer set-up I can increase the relative number of photon realities sets collapsing at D_2 versus the ones going toward the bomb and thus increase the probability of the bomb not exploding and yet being detected.
- In the case neutrons are used, the key is which set of reality connects with what first, the object or the detector, as each reality has its proper time. The monadic spaces reality that reaches the object but fails to connect with the object virtual photons/gluons renders the set of realities going to D_2 complete at that instant. The other realities are eliminated by the selection of time history at the object at that instant. Photons make a selection by space location while neutrons do it by time and space.

3. Wave-particle duality

The "same photon" cannot be observed at both detectors, or at both a detector and the object at the same time because the photon multiple-reality localizes itself as a result of relations with localized quanta (atoms) as Section V described, not because of a so-called wave-particle duality aspect of the photon.

An explanation of a phenomenon based upon wave-particle duality, i. e. via the "Complementarity Principle" of present Quantum Theory, cannot describe how the same object is both a wave and a particle. This principle was set by Bohr (1928) in effect to cover up his ignorance (*and stop his imagination, thus Science*) about the true makeup of the quantum, which in Bohr's mind, following Mach, was unknowable (see Section II). Separately, Heisenberg (1927) with his "Uncertainty Principle" stated, also in the line of Mach's philosophy, that any speculations on the existence of a real world "beyond the perceived statistical world... are sterile," thereby denying the existence of a real world as far as Physics was concerned. Bohr's and Heisenberg's principles provided the foundation of present Quantum Theory (Wheeler and Zurek, 1983), a theory which then ended up as a set of formal principles, not as a constructive theory as many still believe it to be. Einstein (1982, p. 266) in 1931 thought otherwise, stating that "the belief in an external world independent of the perceiving subject is the basis of all natural science." Neither position considers the possibility of a relational world as I describe here. The null-measurement experiment is only one example among many showing the inadequacy of these principles *when they are assumed to be explanatory tools*. Popularizers such as Davies (1996) are then taunting the "wonders" of the quantum, not the inadequacy of the knowledge. This inadequacy should not be a surprise since the principles of Quantum Theory were set to cover up ignorance in the first place. When we will see this theory as the "doctrine" it truly is, as Schroedinger (1935) himself called it, we may at last have the curiosity to do the job Physics has been waiting for us to do all these years.

The duality of waves and particles is thus an experimental fact that has no explanation in the present Quantum Theory but finds one through the monadic spaces multiple reality approach presented here. Notably, the particle picture has only a meaning within a specific path (history) of a quantum (a tree of monadic relations - a "discrete volume frame" in the understanding of Section III), not within the total set of realities making up the quantum, where only monadic spaces exist. Waves of probabilities are the result of Schroedinger's formalism, an incomplete picture of the quantum as Section V explained.

VIII. CONCLUSION

Now that we have spent over 70 years trying to understand the quantum through the dark glasses of a formalism invented purposedly to skip the physical meaning of the processes really going on, it looks to be time to go beyond and finally use our imagination once again to find out what these non-local features of the quantum truly mean and how they could be used besides building bomb detectors. But so far we have seen these non-local features only at the "elementary particle" level, and thus *could use only the local features of the quantum*. With them we did indeed build computers via understanding the solid state (which really is nothing more than sand and stones) and studied Life via the new Chemistry that our knowledge of the *local* quantum made available. But is that all? Is Chemistry alone capable of creating Life? May be Life, with its stunning *whole* (non-local?) entities called "living organisms," has something to tell us physicists about reality that the "dead" world we studied earlier could not. Just maybe. It would be certainly refreshing, and an eye opener. Besides, we will need to firm up the evidence we may get from the sky, and a negative finding in Particle physics is not a positive fact to build upon. As the Big Bang hypothesis rests on a preponderance of evidences, we must get a substantial set of such evidences before a meaningful base for an alternative can be built. Space as generated by its content, the ability of the quantum to create its own space, a key understanding not covered by present quantum theory, may have many effects at a scale in-between the scales of Particle Physics and Astrophysics. New properties of materials may thus be waiting to be discovered here on Earth, and maybe (very) close to us.

APPENDIX A: SPACE GENERATION WITHIN THE VISIBLE UNIVERSE

1. Introduction

Recent data has been interpreted as showing that the universe expansion originally thought by Hubble to be observed is accelerating, or at least has accelerated some time in the past. I shall follow a radically different hypothesis here, where instead of space expanding on a universal scale, it is locally generated through stars in galaxies and the observed redshift of the light received from outside our galaxy corresponds to these local generations of space. Such an approach is corroborated by comparing recent high redshift supernovae surveys data with the known age of the Sun and our galaxy.

2. Space generation

a. The redshift concept

Following the original method by Hubble,[97] a set of standard candles (objects of known luminosity) spread throughout the visible universe has been used to determine the relation between astronomical objects distance and their observed "redshift." The distance is determined by comparing the known luminosity to the flux observed at Earth. Objects whose light was emitted at different times in the past can be evaluated by studying standard candles with different fluxes. The observed redshift of an object has been thought since Hubble to be the shift of the object spectrum to longer wavelengths because of the Doppler shift of the radiation it emitted *due to an assumed recessional velocity from Earth*. If the velocity V does not approach the speed of light c:

$$V = c\,z \tag{A1}$$

with z being the redshift from wavelengths changes between the time they are emitted and the time they are observed:

$$z = (\lambda_{obs} - \lambda_{em}) / \lambda_{em} \tag{A2}$$

The redshift of the object was observed by Hubble as proportional to its distance d :

$$V = c\,z = H\,d \tag{A3}$$

where H is the Hubble constant, with the latest value (Finkbeiner, 1999) known to be 70 km/s-Mpc (at ±8% uncertainty) with Mpc = 3.26×10^6 light-years (megaparsec).

Example: with c = 3×10^5 km/s and $z = .3$, relation (3) gives d = 1,286 Mpc.

b. The space generation theory

Let's assume (Fig. 14) a *high redshift* object on the right is observed from our galaxy on the left.

THE SPACE GENERATION HYPOTHESIS:

- Space is generated by radiation produced through nuclear fusion (e. g. in stars) in proportion to the radiation flux of the source up to a saturation value[98] and displaces the background space relative to the location of the source.

A photon received from the object has gone first through a starting region which the radiation from our galaxy did not yet reach because we are too far away knowing the age of our sun. Within the above hypothesis this starting space is a combination of the background space and the space the high redshift object built by its own radiation. If the photon from the object was observed from that region *it would not have a redshift coming from its travel in that space* (except for residual redshift - see Subsection 4).

Then the photon enters a region at d_e from our galaxy where *space is a combination of the background space (which includes now the object's space) and the space generated by our galaxy*. For the duration of the travel in that region *the photon goes through a space which becomes more and more the space generated by our galaxy closer the photon is from us until it reaches the local saturation area where the space was entirely produced by the galaxy* (Fig. 15). The flux of radiation at distance s from our galaxy with luminosity L is

$$f = L / 4\pi s^2 \tag{A4}$$

From the hypothesis above the corresponding *local spatial scale change* versus the background space is then proportional to $1 / s^2$. For a distance (wavelength) λ crossed by the photon *at distance d* from and towards the source of space, our galaxy, the *spatial scale increase* measured by the increase of distance from the source is proportional to

$$\Sigma \ (1 / s^2 - 1 / (s+ \lambda)^2) \ \sim \ \int_{d_0}^{d} 2 \, ds / s^3 \tag{A5}$$

where the sum is over the λ distance elements between the photon and the space saturation area around our galaxy starting at d_0 (if closer, space originates entirely from our galaxy). Starting at distance d_e the photon experiences this scale increase each period through the connections from the source of space to the common space manifold discrete volume frames (which are infinite in extent - see first Remark below), so when it reaches the distance d the *accumulated* scale increase is proportional to

$$\int_{d}^{d_e} \left(\int_{d_0}^{s} 2 \, ds / s^3 \right) ds \ = \ (d_e - d) / d_0^2 \ - \ (1 / d \ - \ 1 / d_e) \tag{A6}$$

Going further towards the source, with $d < d_0$ the increase of scale versus the originating object space scale stops and the scale becomes constant:

$$\Delta\lambda / \lambda \ \propto \ d_e \tag{A7}$$

If the photon originated from an object at distance $d < d_e$ *the increase in spatial scale from the scale where the photon originated gives an increase in photon wavelength, i. e. a "redshift" proportional to the distance travelled*. The classical Doppler relations (1) and (2) are thus followed (arrived at here from the viewpoint of the photon).

This change of scale is therefore equivalent to a receding speed *V* for our galaxy versus the originating astronomical object. The space generated by our galaxy has then the same effect via the photon travel towards it ***as if*** *our galaxy receded from the originating object at a speed proportional to the distance the photon travelled in our galaxy own space spreading region. The space generation hypothesis thus accounts for the redshift observations that have been made since Hubble and interpreted as a universe expansion.*

When the photon originates from a distance $d > d_e$ the spatial scale change is defined by the age of the source of space, and thus independent from the distance of the object observed. More details about this case will be given below.

REMARKS.

- The Hubble constant over the speed of light H/c is the proportionality constant for relation (A7). Within the monadic spaces concept it represents *the* ***integrated*** *number of monadic connections per unit of travel length* (using Earth as a reference frame) *that the monadic spaces making up the photon* ***fail to have*** *with the infinite discrete volume frames connected to* ***any*** *given source of space they go toward during their travel due to the non-zero number of background frames connected to all* *the other sources*. It would be then a universal constant like the gravitational constant. Such constants would be defined by the scales of the common space manifold (CSM) monadic structure of discrete volume frames, with H/c corresponding to the *symmetrical* content manifolds connections (radiation), and the gravitational constant corresponding to the *asymmetrical* connections (matter). Using the value for H given earlier, $H/c = 7.5 \times 10^{-30}$/cm, thus the CSM (the combination of all generated spaces at a given location) would have the inverse or about 10^{29} symmetrical monadic connections per cm. I shall call the scale corresponding to this concentration the Hubble scale. It is 10^4 larger than the Planck scale (Penrose, 1994, p.338), which would correspond to the asymmetrical connections since the gravitational constant is involved in the definition of that scale, and thus to the relative ability of matter to "warp" the CSM. A "flat" space (no gravitation) would then have a concentration of connections at the Hubble scale while a "sink hole" would have this concentration at the Planck scale. Gravitation would correspond to CSM monadic connections concentrations in-between these two scales.

- The distance d_0 would be fixed by the *net* space generation rate out of our galaxy, which would include both space generation and absorption areas ("sink holes").
- Since the 18th century the so-called "naive" model of the infinite universe (Weinberg, 1972, Chap. 16.1) raised the DeCheseaux-Olbers paradox because in that model the night sky should be bright instead of dark. Here is why. If absorption is neglected, the apparent luminosity of a galaxy of absolute luminosity L at a distance r from a given point in space will be $L/4\pi r^2$. If the number density of such galaxies is a constant n, then the number of galaxies at distances between r and $r + dr$ is $4\pi n r^2\, dr$ while the number of galaxies *visible from that point in space* is $4\pi n r\, dr$ due to the accumulation of galaxies absorbing the light from galaxies farther away in proportion to r. With r_0 being the average distance between galaxies corresponding to n, thus $n \propto 1/r_0^3$, the total radiant energy density due to all galaxies at that point in space is then

$$\rho_s = \int_{r_0}^{\infty} \left(\frac{L}{4\pi r^2} \right) 4\pi n r\, dr = Ln \int_{r_0}^{\infty} \frac{dr}{r} \qquad \text{(A8)}$$

The integral *diverges* logarithmically, thereby giving an infinite energy density and thus the paradox. Now, in the space generation theory as I describe here, photons lose energy according to their travel distance to follow Hubble's relation (this energy loss goes into maintaining the CSM). Then the energy E from galaxies at a distance D is such that $E \propto h\nu = hc/\lambda$ with $\Delta\lambda/\lambda = HD/c$. From (A8) the initial energy will be $dE_0 = Ln/D\, dD$, and

$$dE = \frac{dE_0}{1 + \frac{H}{c} D} \sim \frac{c}{H} \frac{dE_0}{D} = \frac{c}{H}\, Ln/D^2\, dD \qquad \text{(A9)}$$

when $HD/c >> 1$, giving a *background* radiant energy density

$$\rho_b = Ln \int_{D}^{\infty} \frac{c}{H} \frac{dD}{D^2} = Ln \frac{c}{HD} \qquad \text{(A10)}$$

which is *finite*. The divergence (and thus the paradox) has been eliminated. But why is the background dark? The *foreground* radiant energy coming from galaxies closer than D is

$$\rho_f = Ln \int_{r_0}^{D} \frac{dr}{r(1 + \frac{H}{c} r)} \sim Ln \text{ Log } \frac{c}{Hr_0} \qquad \text{(A11)}$$

Since $c/HD << 1$ while $c/Hr_0 >> 1$, $\rho_f/\rho_b >> 1$ and the total radiant energy $\rho_s \sim \rho_f$, accounting for the observed dark background sky surrounding points of light at closer distance.

3. The new observations

Recent observations of about fifty supernovae at "high redshift" z = 0.16 to 0.83 have been obtained[99] with a comparable number of closer supernovae (z < 0.1 - see Fig. 16). The results show that the distant supernovae (for z >.3) are fainter than if they were following the Hubble relation. Figure 16 plots a dashed straight line going upward for the luminosities corresponding to the Hubble relation. The observed brightness is in logarithmic units of "magnitude" versus redshift, which is also on a logarithmic scale.

4. The analysis

a. The meaning of the observations

The data on the observed high redshift supernovae all fall above the Hubble relation straight line. In order to find *the reason for this change from the observed low redshift linear behavior*, I need to find what are the distances corresponding to the redshifts, as such are given in light-years thus correspond to a time in the past when the change happened. I shall then identify this change as most likely corresponding to times before our sun produced a *steady space generation during its existence as a star*. Since the *age of the sun*[100] is 4.6×10^9 years or 1,411 Mpc, the redshift of astronomical objects at the time the sun started shining (and thus started space generation) is $z = .33$. This redshift points on the graph *right where the observed supernovae brightness starts deviating from the Hubble relation*. Due to this coincidence, I have:

CONCLUSION #1:

- The supernovae observational data corroborates the hypothesis of a linear redshift originating with our sun and galaxy space generation.

The graph shows also that supernovae whose light reaches us from before our sun's existence are *not set on a curve (straight line) as the post-sun start supernovae are. These farther ones are instead spread out vertically in brightness magnitude for a given observed redshift*. This feature could be explained through the possibility that, at that time in the past (which was before our sun existed), there was no *steady* space generation provided by our galaxy affecting the area being traversed by the light. Relation 6 would govern, not being in a saturated area of space generation, and thus in general less redshift would be obtained for the same distances travelled by the light coming from the object.

The observed spreads are ***not*** due to observational errors as a substantial number of error bars end way off the Hubble straight line, and no single reasonably drawn curve can fit all the experimental points (the referenced articles draw such curves and none of the published curves pass through all the error bars by far). As it has been pointed out in the referenced articles, the intrinsic value of the supernovae surveys came from the accurate readings of magnitude they allow, unlike other astronomical objects. Hubble and most subsequent observers could not make such precise measurements.

The variability for the same distance would be produced by the objects located in-between. For example, if object 1 in Fig. 17 was close to the path of the photon it would act as a "relay" whereby its space generation would have reached the high redshift object and thus this object would be observed by us to be on the Hubble line.

CONCLUSION #2:

- High redshift supernovae are observed with a ***residual redshift*** *coming from* ***variable*** *space generations affecting the area traversed by the light in the times* **before our sun existed***.*

I shall also note that the grouping of supernovae at greater than .33 redshift does not appear to be an artifice of observational selection. Two separate surveys were made by different teams starting one at .16 and the other at .18 redshift, and both found the supernovae starting at .33 redshift.

Separately, analyses done within the universal expansion model (which then finds the need for a cosmological constant a. k. a. "dark energy") do not account for the spreading of brightness magnitude at equal redshift as observed. If Hubble had observed such spreads he would not have come up with his relation, especially seeing the absence of spread at lower redshift.

b. Astronomy under the space generation hypothesis

As I have just described, going further in the past before the sun started shining the observed residual redshift comes from local space generations traversed by the light on the way from the supernovae, and such space generations are variable, resulting in the spread of brightness magnitudes observed at a given redshift. What counts then is the fact the objects are "standard candles," so in order to get their true distance their observed redshift needs to be *corrected* by assuming the Hubble relation still exists *to make up for the absence of space generation by our sun and galaxy*. This correction is then done by projecting their brightness magnitude horizontally onto the Hubble straight line in Fig. 16.

The objects are then all in fact at a greater distance than they are assumed to be when seeing the Hubble redshift as coming from a universal expansion. Fig. 16 shows that some of the supernovae need to have a redshift greater than 1. Since z = 1 corresponds to 4,287 Mpc or close to 14 billion years, they must be older than 14 billion years (z = 1.3 gives over 18 billion years), and thus older than the age of the universe as now found in the universal expansion model.

CONCLUSION #3:

- The high redshift supernovae are all farther away from us than found through an interpretation of the data using the universal expansion model.

CONCLUSION #4:

- The visible universe is larger than found through the universal expansion model.[101]

5. Overall conclusion

After so many years it is hard to believe we have been led to the wrong conclusion from observations on such a scale. But the understanding of space being generated by stars fits the latest observations in a direct physical way, as opposed to the present unphysical, complex and formal additions[102] (dark matter, dark energy) that have been imagined in order to continue supporting the model of a universe expansion. In contrast, the quantitative part of the present approach is simply Hubble's relation reinterpreted according to the space generation formulation, together with the known age of the sun. Universe expansion theories would place the start of the sun to the left of the graph (Fig. 16) at a redshift corresponding to about 3 billion years through the "universal scale factor" they envision, and thus miss (as they do now) entirely the relationship with the data coming from the surveys. In order to provide a final verification on the meaning of the observed **redshift spreads** as **residual redshifts**, and how far the visible universe goes, *more supernovae with an even higher redshift and/or smaller brightness, if such can be found, will need to be placed on the Hubble graph* (Fig. 16). ***If the space generation hypothesis is correct, there will be supernovae piling up vertically (more and more faint) at a given redshift***, while *any* expansion model can only draw a curve by assuming redshifts come from an overall spatial expansion. The expansion models cannot explain not only the observed spreads in magnitude but also the fact that these spreads exist only past a certain redshift, namely z = .33. On the side of the space generation formulation a method to obtain net rates of space generation by galaxies will need to be established, and the space generation saturation level will have to be quantified. Still, this formulation covers the same facts (Fig. 16) without requiring an ad-hoc "dark energy" with no experimental back-up, and thus Occam's Razor applies, eliminating all the universe expansion theories.

APPENDIX B: A CLARIFICATION OF EVERETT'S INTERPRETATION OF QUANTUM THEORY

1. Introduction

Deutsch (1985) provided an analysis of the physical reality underlying Turing machines, and defined a "quantum generalization" of such machines that he predicted could be more efficient than classical computers. He stated that the most intuitive explanation for the abilities of quantum computers would require Everett's interpretation[103] of quantum theory (Everett, 1957). Deutsch also identified a limitation of such machines for processing information *in parallel*. In order to prove this fact he utilized the present quantum theory viewpoint of a "measurement," that is, he applied a program ζ which makes a "perfect measurement" of the state of the computer from a "macroscopic" level of observation. Seen from Everett's viewpoint, as I shall discuss below, Deutsch then tried to obtain a computation output directly from a quantum subsystem that simultaneously exists in several realities. As a classical observer of the system he could interact with only one of the states from all the possible ones, and thus could obtain only one of the values of his parallelizable function $G(\boldsymbol{f})$ at a time. Therefore he had no choice but to rerun the computation in the hope next time another possible (different) value would be observed. On the strength of this demonstration Deutsch advanced that quantum theory is "a theory of parallel interfering universes."

However, the limitation Deutsch identified is *only based upon the present quantum theory formalism limitations, not inherent limitations of the physical system*. While he took the viewpoint of a *classical* observer as the current quantum theory formalism requires, he could have taken the alternate approach by Everett where the "observer" is instead a *quantum* system interacting with an "object system," thereby defining a *composite quantum system* with it. Such a system may be able to perform a computation also, but Deutsch did not consider it as it has no known formalism in the present quantum theory.

I am going to show that Everett's interpretation identifies the quantum to be in fact more than a set of "interfering universes," and Deutsch's conclusion was rather pointing to the well-known fundamental incompleteness of quantum theory about composite quantum systems (D'Espagnat, 1989). Everett's interpretation then gives, if not a formalism, at least a qualitative *understanding* of such systems evolution when they are restricted to "observer" and "object" subsystems, an understanding *which is not part of the limited view allowed by the present quantum formalism*. Such "simple" arrangements could be in turn used as a base for much more complex composite systems.

2. A clarification of Everett's interpretation

According to Everett's interpretation of Quantum Mechanics, there is no such thing as a "collapse of the (Schroedinger) wave function."[104] "Observations" in the physical world are merely a subset of physical interactions between subsystems of a coherent composite quantum system, *the Universe*.[105] "Observers" are then quantum subsystems part of a *composite system* in which their "states" as defined through the Schroedinger equation are relative to, and locally and physically interact with an "object" subsystem states. Everett's interpretation sees a *deterministic* physical world, being a composite quantum system that realizes fully all the possibilities available when choices are to be made within an evolving system, and these realizations occur in as many "universe branches" (or quantum system realities), *some interfering and some not*, as there are choices. This picture of "states" has been used by Statistical Quantum

Mechanics for composite systems. Unfortunately, the corresponding formalism cannot apply for composite systems with internal fixed ways to "self-observe" as Everett in effect describes. Indeed Everett's viewpoint may be seen as describing a *coherent composite quantum system in which the parts interact ("observe each other") discretely (discontinuously) via quanta exchanges*. Using the Schroedinger equation formalism[106] for such systems *taken as wholes*, Everett then proceeded to demonstrate the following propositions (certain words have been underlined for their importance):

> "A 'good' observation [... is such that (1)] the [object-] system state, if it is an eigenstate, shall be unchanged, and (2) that the observer state shall change so as to describe an observer that is 'aware' of which eigenfunction it is." [Quote A]
>
> "With each succeeding observation (or interaction), the observer state 'branches' into a number of different states. Each branch represents a different outcome of the measurement and the *corresponding* eigenstate for the object-system state. All branches exist simultaneously in the superposition after any given sequence of observations." [Quote B]

The following will be inferred from the above propositions and Everett's related analysis contained in his referenced paper (next Subsection will give a formal backup):

1. Everett's definition of "observers" includes the case when the interaction does not result in a choice of outcome for the object system state, and the observer state may change but a new reality is not generated (since then only one outcome is possible from the interaction, a direct negative of Everett's Quote A above, when qualified by Quote B).
2. In other words, a given observation by an observer will split the original reality into a new set of realities for the observer *only* when it can have *different* possible outcomes (as a direct negative of Quote B).
3. The realities of the composite quantum system that correspond to the states of the object subsystem expand upon interaction to include the observing quantum subsystem (per Quote B above, "the observer state branches," *nothing else*; also an obvious meaning from the superposition equations in the paper)

Another key proposition from Everett is as follows:

> "Any observation of a quantity B between two successive observations of quantity A (all on the same object-system [and not commuting with B]) will destroy the one-to-one correspondence between the earlier and later memory states [of the observer] for the result of A." [Quote C]

The inferences here are:

1. Two successive observations of, or interactions with *commuting* (or identical) quantities will keep the one-to-one correspondence between the observations/ interactions while the observer subsystems branch in separate realities per the earlier quotes (as the negative of Quote C above).
2. The realities created through observing commuting quantities can *merge back* through a later observation, resulting in the phenomenon of "interference" by subsequently observing the object-system in the merged reality (as a consequence of the realities one-to-one correspondence maintained during the evolution of the system from Quote C and the inference above).
3. When created from observations of *non-commuting* quantities the composite quantum system realities never "come back together" (from the word "destroy" in Quote C). Quote C then describes the origin of *irreversibility* for the evolution of the system, i. e. its "arrow of time."
4. Since observations are but a subset of physical interactions, the two kinds of reality branchings

effected by observers in a composite quantum system as described in inferences 2 and 3 above can occur within such a system without the "macroscopic" observations considered in the usual quantum theory.

Quote C permits one to infer Heisenberg's uncertainty principle (Heisenberg, 1930) as Everett's paper did. This axiom of conventional quantum theory could be seen in turn as reflecting the necessity for non-interfering realities within a composite quantum system, as identified in inference 3 above.

Finally, I will infer[107] from Everett's views (the "observer that is 'aware' of" part in Quote A) that

- The quantum subsystems within a composite system *perceive* their own evolution within a given reality branching path as a continuous evolutionary process, while they remain "unaware" of the other realities, except (1) in the event "interfering" realities merge back, which then allows what quantum theory considers an "interference," i. e. a complex number sum of the hitherto separate realities, (2) through an observation, one at a time, of a "non-interfering" reality from another reality.

3. Feynman's postulates and Many-Worlds

Everett's interpretation took as its starting point the Schroedinger equation for the system under study (which was referred as "process 2" in Everett's 1957 paper). However, as we have seen earlier, such a differential equation cannot be postulated in general for *subsystems* of composite systems. Since in the Many-Worlds view observers are considered part of the quantum system under study, it assumes a composite system, and relying entirely on the Schroedinger equation to describe the evolution of observers as such subsystems would therefore be *mathematically inconsistent.* I need to start from a postulate inherently valid for composite systems, which contains the Schroedinger equation as a particular case. Feynman's space-time path integral approach permits such a general formulation. (Feynman, 1948; Feynman and Hibbs, 1965) It will allow me to deduce the main principles of Many-Worlds and to mathematically support the inferences presented in the previous Subsection. The discussion will be limited to such principles, and to those inferences that are not obvious.

a. Feynman's postulates

The definition of the *action* of a mechanical system between times t_a and t_b is given as:

$$S = \int_{t_a}^{t_b} L(q, q, t)\mathrm{d}t \tag{B1}$$

where L is the system Lagrangian and q is a set of *generalized variables*.[108]

A space-time path $q(t)$ is then mathematically defined as a *measure* over the compact [t_a, t_b], physically meaning a trajectory of the system going from point a at time t_a to point b at time t_b within the *generalized configuration space* of the variables q. Equation (1) could be interpreted as an action over the path $q(t)$ between a and b, S[b, a]= $S[q(t)]$, since L does not depend on derivatives higher than the velocity.

Each path is then postulated by Feynman as having a *probability amplitude*

$$\Phi[q(t)] = \text{Constant . } \exp(\frac{i}{\hbar} S[q(t)]) \tag{B2}$$

with $\Phi[q(t)]$ and $S[q(t)]$ understood as *functionals*[109] of the measure $q(t)$.

Feynman further postulated that *all* paths from point a to point b contribute to (i. e. "interfere" to give) a *total probability amplitude*, through an integral over the paths:

$$K(b, a) = \int_a^b \exp(\frac{i}{\hbar} S[q(t)]) \,\mathcal{D}q(t) \tag{B3}$$

This *complex number* $K(b, a)$, called a "kernel" in integral equations theory,[110] is in Physics a "*propagator*" for the system.[111] It represents the system probability amplitude at point b when it is known at point a.

A *wave function* is separately defined by Feynman as

$$\psi(q_2, t_2) = \int_{-\infty}^{+\infty} K(q_2, t_2; q_1, t_1)\psi(q_1, t_1)dq_1 \tag{B4}$$

where *the total probability amplitude to arrive at a particular place is independent of the path followed to reach it*. This definition however presupposes that

$$S[b, a] = S[b, c] + S[c, a] \tag{B5}$$

as this *allows separating the future from the past* and obtain a differential equation for the path integral where ψ is a solution independent of the past history of the system.

b. Composite systems postulate

Now I postulate a system made out of two parts, one I shall call the "system" and the other the "observer," which could be a "measuring instrument," and with interactions present only at specific moments in the evolution of the total system. I shall call this postulate the *postulate of complexity,* as an analog to DeWitt's postulate (DeWitt, 1970a, 1970b) where "the universe is sufficiently complex so it can be divided into systems and apparatuses." The Lagrangian will be then the sum of three components L_S, L_M , and L_{int} , L_{int} being the interaction Lagrangian between the two parts. The propagator for such a system can be expressed as

$$K(b, a) = \int_a^b \int_a^b \exp\frac{i}{\hbar}(S_S[q_s(t)] + S_M[q_M(t)] + S_{\text{int}})\, \mathcal{D}q_S(t)\, \mathcal{D}q_M(t) \tag{B6}$$

Here relation (5) does not hold for each subsystem as I cannot separate the future from the past throughout its evolution. I will say that they are *nonseparable*. *They cannot have a wave function defined,* or have one which remains valid across their entire evolution (see Feynman's discussion). So the wave function concept cannot be used in a composite system formalism throughout its evolution, only the propagator can be. This is where Feynman's approach is more general than Schroedinger's.

Now, from equation (6), I identify separately the integral over the paths available for system M (the observer):

$$K(b, a) = \int_a^b \exp(\frac{i}{\hbar}S_S)\ T[q_S(t), q_M(t)]\ \mathcal{D}q_S(t) \tag{B7}$$

with

$$T[q_S(t), q_M(t)] = \int_a^b \exp\{\frac{i}{\hbar}\int_{t_a}^{t_b}(L_M + L_{\text{int}})dt\}\ \mathcal{D}q_M(t) \tag{B8}$$

The total amplitude of system M is thus the sum of the amplitudes over all the paths it follows corresponding to a given path of system S (the observed system).

Since the total amplitude given by (7) is an integral over *definite* paths, the probability amplitude meaning as given by Feynman can readily be replaced with an equivalent *deterministic* meaning under which *each path is in fact taken by the system*, branching at a in as many realities of its initial reality, following then a specific path between a and b, with ultimately all the realities merging ("interfering") back at point b such that there is a *definite phase* for the system at b represented by $K(b,a)$. With this reinterpretation, Feynman's postulate on "interference" between all possible paths matches the Many-Worlds viewpoint [This supports Quote C, inference 2 of previous Subsection].

So equation (8) then represents *an observer system for each of the observed system paths*. The action of the interaction S_{int} can only be associated with system M because it is an observation of system S by M. Mathematically, the measure $q_M(t)$ of the interaction is associated with the system M path integral, not with the system S integral.

c. A composite system analysis set-up

To be able to represent an observer/observed system relationship while complying with the postulate of complexity, I must assume that *the observer does not continuously observe the system*.[112] L_{int} needs to reflect this physical situation. To pursue the analysis in details I will assume (1) a sequence of observations at times α, β, γ, τ, (2) the observations occur on different variables of system S such that

$$L_{\text{int}} = f[q_{S_1}(t)]\delta(t-\alpha) + f[q_{S_2}(t)]\delta(t-\beta) + f[q_{S_1}(t)]\delta(t-\tau)) + g[p_{S_1}(t)]\delta(t-\gamma) \tag{B9}$$

with $\alpha<\beta<\gamma<\tau$, and (3) system S has 4 variables $q_{S_1}, q_{S_2}, p_{S_1}, p_{S_2}$, with the q's and p's being conjugated variables, i. e. satisfying the commutation relations

$$[p_i , p_j] = 0 \qquad [q_i , q_j] = 0 \qquad [p_i , q_j] = i\hbar\delta_{ij} \tag{B10}$$

The observations are thus represented by δ measures (measures of mass 1 concentrated at one point, i.e. "Dirac functions") with α, β, τ observations being done on variables q while γ is done on variables p. Such a representation is justified as interactions between subsystems may be *discontinuous* in time, e. g. when the subsystems are spatially localized and when interactions occur via exchange of quanta at specific moments of the subsystems evolutions. A certain non-zero amount of action then corresponds to that instantaneous exchange.

I will use the rule described by Feynman stating that "amplitudes for events occurring in succession in time multiply." It is expressed by:

$$K(b,a) = \int_{q_d}\int_{q_c} K(b,d)K(d,c)K(c,a)dq_d dq_c \tag{B11}$$

where the paths go from a to c, then to d and finally to b in time. To simplify the notation I will replace the integral signs by sums and separate the variables:

$$K(b,a) = \sum_c K_c(c,a)\sum_d K_d(d,c)K_d(b,d) \tag{B12}$$

d. Observation α

Before observation α the two subsystems are evolving separately, and therefore each have a defined Schroedinger equation to represent their evolutions. Upon observation α, expressions (8) and (9) give:

$$T_{\alpha_i}[q_M(t)] = \int_a^b \exp\frac{i}{\hbar}(S_M + S_{\text{int}}).\exp(\frac{i}{\hbar}f[q^i_{S_1}(\alpha)])\ \mathcal{D}q_M(t) \tag{B13}$$

Functional T then is replaced by a set of functionals, one for each path the system S was following at time α. Equation (7) in the notation (12) gives for the overall system:

$$K(b,a) = \sum_i K_i(\alpha,a)\int_\alpha^b \exp(\frac{i}{\hbar}S_{S_{\alpha_i}})T_{\alpha_i}[q_M(t)]\ \mathcal{D}q_S(t) \tag{B14}$$

In the above formula $S_{S_{\alpha_i}}$ is the action of a path $q_i(t)$ of system S as observed at time α by system M. The overall system evolution will be represented by :

$$K(b,a) = \sum_i K_i(\alpha,a)K_i(b,\alpha) \tag{B15}$$

with, from (14):

$$K_i(b,\alpha) = \int_\alpha^b \exp(\frac{i}{\hbar}S_{S_{\alpha_i}})T_{\alpha_i}[q_M(t)]\ \mathcal{D}q_S(t) \tag{B16}$$

After observation α a separate Schroedinger evolution occurs (no interaction between subsystems) corresponding to each of the functionals of expression (13) spawned by the observation [supporting Quote B in the previous Subsection identifying separate evolution branches]. The wave function of the system for each functional i is:

$$\psi_i(q,t) = \int_{-\infty}^{+\infty} K(q,t\,;q_{\alpha_i},\alpha)\psi(q_{\alpha_i},\alpha)dq_{\alpha_i} \tag{B17}$$

Within a given complete set of orthogonal solutions φ_k of the Schroedinger equation corresponding to the integral equation above, the *complex sum of paths* among all the paths that can be observed (within a specific history) having a given eigenstate is fixed [supporting the superposition principle of quantum theory and the probabilistic meaning of the coefficients therein]. For each of the φ_k of the observed system there will be then an observer system evolution. The original observer system will be then in multiple realities, one for each subset i of paths as described above existing at time α. Each *observer system reality* then follows its own evolution according to the functional T in expression (16) in "parallel" with the corresponding *observed system paths* [This supports Quote B and its inference 3 in the previous Subsection. Quote A is supported by expressions (13) and (16) where the path observed is *recorded* by the observer system reality in the corresponding propagator expression segment]. I shall also note that a propagator segment (16) may very well have a zero value, thus the corresponding subset of paths has no corresponding observer system reality. (There is no such thing as a "non-observer.")

e. Observation β

Now I reach the time β for the second observation, which is done on another q_S variable. According to (13):

$$T_{\alpha_i\beta_j}[q_M(t)] = \int_a^b \exp\frac{i}{\hbar}(S_M + S_{\text{int}}).\exp(\frac{i}{\hbar}\,f[q^i_{S_1}(\alpha)]).\exp(\frac{i}{\hbar}\,f[q^j_{S_2}(\beta)])\,\mathcal{D}q_M(t) \tag{B18}$$

Equation (14) becomes:

$$K(b,a) = \sum_i K_i(\alpha,a)\int_\alpha^\beta \exp(\frac{i}{\hbar}S_{S\alpha_i})T_{\alpha_i}[q_M(t)]\mathcal{D}q_S(t)\sum_j\int_\beta^b \exp(\frac{i}{\hbar}S_{S\beta_j})T_{\beta_j}[q_M(t)]\mathcal{D}q_S(t) \tag{B19}$$

or, in my notation:

$$K(b,a) = \sum_i K_i(\alpha,a)\sum_j K_i(\beta,\alpha)K_j(b,\beta) \tag{B20}$$

The new variable being independent from the previous, each observer system reality has branched into j observer realities (represented by the various components of the sum in (20)). Within a given history ij (one of the terms of $K(b,a)$), each observer reality i becomes one of the j observer realities, thus perceiving an apparent random sequence of definite values for the variables q_S. [This supports Everett's relation of Many-Worlds determinism to conventional quantum theory nondeterminism.]

I could have put expression (20) as

$$K(b,a) = \sum_i\sum_j K_i(\alpha,a)K_i(\beta,\alpha)K_j(b,\beta) \tag{B21}$$

Since the individual propagator segments *add up*, the various reality branches of the system then continue to "interfere" [This supports Quote C and its inferences 1 and 2]. Each term of the sum contains data from the previous evolution segment, thus the "memory" on which branch it went through is maintained [This supports the branch communication inference of the previous Subsection]. Since variations on the paths observed at α and β commute (are exchangeable) per relations (10) the evolution of each propagator branching across its two segments is reversible in time [This supports in part Quote C].

If the observation β is done on the same variable as in observation α, the same eigenstate will be observed and the observer realities are not branched. The overall system propagator is then:

$$K(b,a) = \sum_i K_i(\alpha,a)K_i(\beta,\alpha)K_i(b,\beta) \tag{B22}$$

The observer system realities effectively "follow" the observed system evolution each "from a different angle." The observed system reality has a state *relative* to the reality which observed it [as Everett identified in his paper].

f. Observation γ

This time conjugated variables p_S are observed. The measure of the interaction is then associated with the conjugated variable representation of each propagator segment $K_j(b, \gamma)$ starting at γ. I will add a prime to the sum symbol to signify the sum is defined on a different path representation of the *overall* system. Expression (21) becomes

$$K(b,a) = \sum_i \sum_j K_i(\alpha,a) K_i(\beta,\alpha) K_j(\gamma,\beta) \sum_k{}' \int_\gamma^b \exp(\frac{i}{\hbar} S_{S_{\gamma_k}}) T_{\gamma_k}[p_M(t)] \mathcal{D}p_S(t) \qquad \text{(B23)}$$

or:

$$K(b,a) = \sum_i \sum_j K_i(\alpha,a) K_i(\beta,\alpha) K_j(\gamma,\beta) \sum_k{}' K_k(b,\gamma) \qquad \text{(B24)}$$

with:

$$T_{\gamma_k}[p_M(t)] = \int_\gamma^b \exp\frac{i}{\hbar}(S_M + S_{\text{int}}).\exp(\frac{i}{\hbar} g[p_{S_1}^k(\gamma)])\, \mathcal{D}p_M(t) \qquad \text{(B25)}$$

T is now a set of functionals of a conjugated function, i. e. of a path in a new representation. A new branching of observer systems realities occurs as in observation α, but in their propagator segments there is no longer any *relationship data* for each observer reality to the previous collection of paths *i*, following now paths of conjugated variables. I could picture this feature through a given observer reality tied previously to an observed system variable. Since at time γ it observes rates of changes, it cannot observe the rate of change of the variable it was following. The commutation relations (10) express this fact mathematically. Therefore a given observer system reality has no choice but to observe one of the paths of system S *at random*. In formulae (23) and (24) there is no parameter available to tie each term of the last sum univocally to a term of the previous sum. Consequently, a given history cannot be "retraced" as the physical information is not there to do the backwards evolution in time. The propagator segments after time γ cannot be represented as one system since they do not contain the information to put them together univocally. The various realities are then no longer an interfering set of system realities [This supports Quote C and its inference 3].

The evolution of the observer system becomes tied to the set of orthogonal wave functions corresponding to conjugated variables p_S. Variables q_S are now free to evolve in the system S independently of the observer realities.

g. Observation τ

Now the observation is on the q_S variables. I have then a repeat of the observation γ functional *T* switch to a conjugated function, this time to the earlier one. The overall system propagator becomes:

$$K(b,a) = \sum_i \sum_j K_i(\alpha,a) K_i(\beta,\alpha) K_j(\gamma,\beta) \sum_k{}' K_k(\tau,\gamma) \sum_l K_l(b,\tau) \qquad \text{(B26)}$$

There is now a multiplicity of observer system realities corresponding to the same variables q_S, because each reality has experienced a different random *non-reversible* sequence of functionals *T* (a different history).

h. Addition of a second observer

Going back to expression (6), (7) and (8), I could have a second observing system N interacting with the system S at time $\theta>\tau$ through the q_S variables. The overall system evolution would be expressed by:

$$K(b,a)=\int_a^b\int_a^b\int_a^b \exp\frac{i}{\hbar}(S_S+S_M+S_N+S_{MS\,\mathrm{int}}+S_{NS\,\mathrm{int}})\mathcal{D}q_S(t)\mathcal{D}q_M(t)\mathcal{D}q_N(t) \quad \text{(B27)}$$

$$K(b,a)=\int_a^b \exp(\frac{i}{\hbar}S_S)\ T_M[q_S(t),q_M(t)]\ T_N[q_S(t),q_N(t)]\ \mathcal{D}q_S(t) \quad \text{(B28)}$$

$$T_N[q_S(t),q_N(t)]=\int_a^b \exp\{\frac{i}{\hbar}\int_{t_a}^{t_b}(L_N+L_{NS\,\mathrm{int}})dt\}\mathcal{D}q_N(t) \quad \text{(B29)}$$

Since L_{NSint} does not act until past time τ, systems N and S are independent from each other until that time. Expression (26) represents the evolution of system M as an observer of system S within composite system (S, M), even after the observation by system N because *observations inherently do not affect the evolution of system S*. Thus a new composite system (S, M) can be defined with the propagator:

$$K(b,a)=\sum_m K_m(\theta,a)K_m(b,\theta) \quad \text{(B30)}$$

Then, after the observation by system N at time θ of a variable q_S in system S, observer N reality is branched by observing system S paths at time θ, as observer M reality was in observation α.

If on the other hand the second observer interacts with the first instead of system S, through one of its variables, expressions (28), (29) and (30) become:

$$K(b,a)=\int_a^b \exp(\frac{i}{\hbar}S_S)\int_a^b \exp\frac{i}{\hbar}(S_M+S_{MS})T_N[q_M(t),q_N(t)]\ \mathcal{D}q_M(t)\ \mathcal{D}q_S(t) \quad \text{(B31)}$$

$$T_N[q_M(t)q_N(t)]=\int_a^b \exp\{\frac{i}{\hbar}\int_{t_a}^{t_b}(L_N+L_{NM\,\mathrm{int}})dt\}\mathcal{D}q_N(t) \quad \text{(B32)}$$

$$K(b,a)=\sum_i\sum_j K_i(\alpha,a)K_i(\beta,\alpha)K_j(\gamma,\beta)\sum_k{}' K_k(\tau,\gamma)\sum_l\sum_m K_l(\theta,\tau)K_m(b,\theta) \quad \text{(B33)}$$

Therefore the second observer reality is branched into all the existing branches of the first observer. I have now a composite system made of three parts. The reality branch of the first observer expands to include the second observer upon interaction (and obviously to include nothing else) [This supports Quote B inference 3].

If subsequently the second observer observes the first observer *a second time* on a variable *conjugated* with the previous one, its reality will be branched as the first observer reality was earlier in observation γ while erasing its propagator segment connection data. Within a given history *ijklmn* (*n* being the index of the next term that will appear in (33)) it will then "get into" any one of the first observer existing reality branches *at random* being now its own reality branches [This supports the branch communication inference].

i. Future developments

I note that (1) the above formalism does not attempt to differentiate the individual evolutions corresponding to each propagator reality branch segment, but a Lagrangian in a suitable form (measure-wise) could possibly handle such a differentiation, (2) the instants of the observations have been identified as fixed while they ought to have been entered in the observation measures as themselves functions of the observer and/or observed systems variables, (3) the case of a system S that would be affected through the observation process has not been covered (it relates to, for example, an atomic nucleus that is observed through its emitted decay particle) and could be handled by explicitly formalizing the composite nature of S in that case as a set of observer subsystems which definition would include the ability to observe and be observed ("reciprocal observers"). The departure of one of the observers at a given instant in a given propagator segment could be represented by a measure non-zero up to that instant, and the instant being necessarily a function of all the systems variables, the system composition *definition* being itself changed. Such an event in the affected propagator segment would then affect in turn all the contemporary observers propagators segments, coming from a common term in the Lagrangian of the system.

The above possibilities could be investigated in a study with the goal to establish a formalism able to handle specific composite systems set-ups and their interactions.

4. Conclusions

Present quantum theory and "quantum computers" theory can only use a classical "observer" *non-deterministically* tracking the quantum system it observes performing a computation in interfering realities (as Deutsch pointed out), and thus can only obtain statistical results from the subjacent multiple realities.

But "interferences" among realities occur only with *observations of interfering realities, such "observations" being the only kind addressed by the quantum theory formalism* (with "observation" understood to be at the coherent quantum level). Then, in order to obtain *separate* results of several computation reality branches in a computational run, "non-interfering" realities need to be created and collected at a coherent quantum level, not at the "macroscopic" level as the present "quantum computer" theory proposes, that is, before decoherence destroys the branched realities relationships. Each of these non-interfering realities could be then observed one at a time without rerunning the computation. The characteristics of a "non-deterministic" computation in the sense of Computer Science (Aho *et al.*, 1974) would be thereby available. Such quantum set-ups could possibly display greater computational capabilities than what is obtainable through the present definition of "quantum computation." However, the other characteristics of a composite system quantum computation will need to be evaluated before making a definite conclusion on this matter.

Also, a complete formalism remains to be worked out for the kind of composite quantum systems identified here.

APPENDIX C: SUMMARY OF POTENTIAL THEORETICAL STUDIES

1. Mathematics

---A continuum without Axiom of Choice, using a superposition of discrete volume frames of monadic relations (the "structured" continuum of Section III).
---The notion of monadic relation (Section V) as a computational step using the base speed postulate (Section IV).
---The transition from algebraic objects defined through the structured continuum to the usual analytic ones (integrals, tensors, etc) (Section V).
---The transition (correspondence) from the common monadic (algebraic) space manifold to the classical continuum Riemanian/Einsteinian manifold ("spacetime") (Section V).
---A group of 3D monadic relation space manifolds that self-generate through the connections between each other - one of the manifolds is generated by all the others that are then considered its "content" and all spaces are essentially transitory, dynamical versus each other (Section V).
---Formalize multiple-reality generation from choices in monadic relations of the "content" coming (1) from asymmetries in the relations within manifolds and (2) from the separate evolutions of nuclei monadic spaces (Section V).
---Formalize the evolution and lifetime of a monadic space manifold (Section V).

2. Physics/Astrophysics (some may belong to Mathematics)

---Relate monadic spaces dynamics to the Schroedinger/Dirac/Heisenberg/Feynman formalism of particle dynamics, i. e. the quantum version of the Lagrange/Hamilton formalism (Section V).
---Formalize the process leading to the reorganization of monadic space manifolds including confined/free and free/confined "content" relations, including the "folding" of the common space manifold into content manifolds and its relations with the constants of Nature (Section V).
---The value of a quantum in terms of amount of space in the monadic space picture and its connection to the zero-point energy (Section VI).
---The cosmological continuity equation (Section VI).
---Formalize the notion of non-interfering realities in composite quantum systems at large (Appendix B).
--- Analyze a composite quantum system with parts at macroscopic distances from each other (Section VII).

3. Computer Science

---Extend the notion of computation to an infinite multiple reality system with undistinguishable elements (Sections III, IV, V).

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Notes

[1] Per Einstein's quote "I am enough of an artist to draw freely upon my imagination. Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world" (Viereck, 1929), and Bronowski (1958).

[2] A first lesson to draw here: Watch out for the Obvious as handed out by Nature and conventional wisdom!

[3] See Dover translation in refs.

[4] Many references on the history of Mathematics, which is most of the history of Science until modern times, describe this story, the authoritative textbook is Eves (1989).

[5] The contribution of Galileo is covered in details by Drake (1978 and 1990).

[6] In other words, Galileo gave us the "principle of equivalence," that was subsequently ignored by Newton and rediscovered 300 years later by Einstein (who acknowledged this in p.287 of Einstein, 1982), the perfect example of a basic concept taking centuries to be understood!

[7] The birth of classical physics can be studied in many books, one of which is Dugas (1988).

[8] Many books describe Einstein's intuitions, one of these is Pais (1982).

[9] Mach's logical positivist philosophy can be better understood through others' perceptions, such as Einstein, Schrodinger and Feynman's. His original work is in Mach (1883).

[10] Or Mach's followers, as Mach died in 1916. A vocal group supported his philosophy in the 1920s and 30s (see Miller, 1996).

[11] The history of quantum mechanics can be gleaned from biographies such as Moore (1989) and review books such as Miller (1994).

[12] Among many descriptions of Bohr's philosophy, see Crease and Mann (1996) and Wheeler (1994).

[13] I will not list the key reference works and textbooks on Quantum Mechanics as they are too numerous. Three textbooks are listed in the refs.: Cohen-Tannoudji *et al.* (1977), Dirac (1958) and Sakurai (1994).

[14] For a popular introduction, see Hawking (1994).

[15] Misner *et al.* (1973) - §7.1 and Box 18.1 where "spin-2," i.e. gravitons, derivation of Einstein's equations is shown as being an "unphysical and incomplete mathematical artifice." Compare with next footnote.

[16] See previous footnote and Weinberg (1993), p.300 note for p.141 "there is no serious doubt of the existence of gravitons." Weinberg (1993) heavily criticized logical positivism, apparently not identifying

his own attitude as closely following that philosophy, especially in its *pan-mathematical* aspect. 20 years earlier (Weinberg, 1972) he presented his *mathematical* "alternative" to Einstein's physical approach in the line Feynman adopted in the 1960s, and in sharp contrast with Wheeler's position (Misner *et al*., 1973).

[17] For a scathing diatribe see Lerner (1992). There is also a large number of books on the "understanding" behind our present mathematical theories, such as Teller (1995) and Auyang (1995). I cannot find any real understanding in them. In fact they tell me that there is no understanding.

[18] Through mathematical analogies. Gravitons came from such analogies because we don't know what a field really is, we know only its mathematical shape. The Yukawa exchange forces across nucleons came also from an analogy, and, even though this theory was rewarded with a Nobel prize, it was later on found not to match reality (Aitchison and Hey, 1989). The so-called "Grand Unified Theories" (Kaku, 1994, 1995) are all based on mathematical analogies, not physical insights like Einstein had. We don't know the *physical* reasons behind these analogies, as they do not provide a physical meaning. No new physical features are imagined. Some work, some don't. As Aitchison and Hey wonder, they just replace one question by another, what is behind these analogies? Such theories are examples of non-constructive thinking in the line of Mach's philosophy, a line which can of course provide material for theses, but also can easily lead to sidetracks and waste of time (and money) impossible to recognize as such.

[19] Reston (1994) - Bellarmine, who judged Galileo and Bruno, was a Jesuit.

[20] Read Feynman vs. the superstring theorists on this in Mehra (1994). The artificial basis of the Higgs field hypothesis will be discussed in Section V.

[21] David Deutsch (1997) tried to get away from this doom via Tipler's "Omega-Point" theory but this attempt looks very artificial.

[22] Newton's space has no predefined scale. Many have thought previously that maybe our spacetime is of a fractal nature, with no end at the bottom or top, but this view can't include the quantum and its key function to differentiate things at a certain scale in an infinite superposition. Sections IV through VI will elaborate.

[23] Leibniz as quoted by Berkeley in p.249 of Dunham (1990).

[24] Cantor's diagonalization method ows its one-to-one correspondence approach between members of infinite sets to Galileo, who knew full well its physical limitations, unlike Cantor who was not preoccupied with applying it to the real world. Galileo explains the origin of the method in the "first day" of Galilei (1954).

[25] See p. 347 of Einstein (1982) and Hocking and Young (1988).

[26] D'Espagnat (1995) Chapters 8 and 9.

[27] The use of metaphors in Physics has been debated for many years as discussed in Miller (1996). Heisenberg in the 1920s and 30s and Feynman in the 1940s and 50s followed the line of Mach and understood metaphors as to be generated from the formalism obtained from experimental data. This view went against Boltzmann's and Einstein's who maintained that "unclarities in the principles of mechanics" result if metaphors generated from experimental data do not originate the formalism. I follow a combination of both views.

[28] Dirac invented the "function" bearing his name, the "delta" function, by a physical reasoning of the sort above, which, again, is very unsound mathematically. It took 15 years for L. Schwartz to find a formalism for it. By then Dirac had used his function in many ways, and Schwartz had enough examples of use to "acquire" the meaning that Dirac put in his instrument. See Schwartz (1966).

[29] Einstein (1982) p.348, reprint of a 1950 article in Scientific American, and p.375 "Relativity and the Problem of Space," reprint part of a revised edition of Einstein (1954).

[30] Aitchison (1985), Milonni (1994), Penrose (1991b).

[31] Dirac (1996) p.62.

[32] Leibniz (1989) p. 334.

[33] As expounded in Misner *et al.* (1973) for example.

[34] See Mc Intyre (1903) p.343 (paraphrase).
[35] Although an alternate source of metaphor based on our mind's eye could be the Julesz imaging system creating an "internal" space out of its "content," see Casti (1994), p.117-119 and Thing Enterprises (1993).
[36] See Schweber (1994) for the historical details.
[37] Many discussions have been held about reality at the "Planck scale" where ultimately space may be discrete, but such discussions involve the concept of spacetime found in Relativity, itself taken as having an existence on its own, a hypothesis with no experimental backing and at odds with the one of this study.
[38] It would be interesting to see what would happen to renormalization theory in a 3x3-D multi-reality world as I consider later on, as in such a world particles are no longer "punctual," they are spaces in themselves with a non-zero measurable connection across realities with our ordinary 3-D space.
[39] See review in Schweber (1994) and Mehra (1994).
[40] Mach's principle was his main contention about the incompleteness of General Relativity, as Einstein's theory did not explain the origin of inertia. See Gribbin (1995) p.178. This principle is non-constructive in the sense that it hides the connection of the common monadic space manifold to the matter/radiation manifolds as discussed in next section. Also, some people see Mach's principle as implying inertia is variable, i.e. "anti-gravity" exists. See Woodward (1990) for a method to transform electrical power into mechanical energy through transient changes in massive *energy density*. Inertia is **not** modified by such a process, only the matter/radiation energy density tensor is (the spread of mass in space). The electromechanical set-up only performs this modification fully in agreement with General Relativity, nothing more. So it definitely does not prove "anti-gravity" as some people claim.
[41] Hocking and Young (1988). See p. 123 for Peano curves.
[42] The term "internal" is used in present-day physics without a description of its meaning. Next section will give it one.
[43] See Gottfried and Weisskopf (1986). A neutrino is a particle which has a "helicity" (the projection of the spin on the momentum vector) like the photon but has a half integer spin like the electron, and is "left-handed" instead of being evenly handed (only a positive helicity seems to exist, making our universe "non-chiral").
[44] There is no information that can be passed between classical observers, so classically causality is not violated, but if one remains within the quantum level there is a single "extended" system that "knows" instantaneously what happens to its various realities - this fact has been experimentally proven as a feature of our reality through Alain Aspect's experiments in 1982 (Section VII).
[45] See Gaveau and Schulman's papers for details.
[46] I interpret Bruno's and Leibniz's ideas freely in light of what we know now about our reality. As a reference, see *The Monadology* section in Leibniz (1989) and also Mc Intyre (1903).
[47] An integral as an uncountably infinite process is very different from a sum, even infinite such as a series, which is a discrete process. Unseparability involves the former process.
[48] Thomson (1961) p. 157 has pointed out that some living organisms (radiolarians) display arrangements similar to the ones considered here.
[49] Of course this problem needs really to be looked at for a 3D sphere embedded in a higher dimensional space, and then Plato's regular polytopes would have to be considered as "tiles," instead of polygons.
[50] Sakurai (1994) p.126.
[51] Penrose (1991) p. 218.
[52] Okun (1989) p.31.
[53] Gottfried and Weisskopf (1984) p. 159 use Schroedinger's equation but here the relativistic Dirac picture is needed since spin enters in the process to be described.
[54] Aitchison and Hey (1989); Ramond (1990); Faddeev and Slavnov (1991).
[55] See p.160 of Gottfried and Weisskopf (1984).

[56] For a vivid description of SU(2) rotation perceived as a rotation in a plane translating in an orthogonal direction to itself within our common space, see Feynman (1987).
[57] Fuller (1975) Section 465.
[58] See Gottfried and Weisskopf (1984) p. 154 for a summary of the Standard Model.
[59] See Joshi (1977) p. 176 and Wybourne (1974) Section 20.
[60] See p.94 of Gottfried and Weisskopf (1984).
[61] See p. 60 of Gottfried and Weisskopf (1984).
[62] See p.168 of Gottfried and Weisskopf (1984).
[63] That's why also quantum field theorists hang on to the notion of space as an arena filled with "gravitons": That way there is the potential for a symmetry to break in a space that exists by itself. This is the perfect example of a mathematical deduction done in a vacuum, literally.
[64] Glanz (1999) puts the Higgs boson discovery by the end of 2000 and the confirmation of its absence by 2004 or 2005.
[65] See p.165 of Gottfried and Weisskopf (1984).
[66] See Note 40.
[67] See the later section on "extended computation."
[68] My position is very different from Penrose's (see Penrose, 1991 and 1994) as he thinks that only gravitation-induced wave function collapses are uncomputable. His position reflects the fact he still maintains the view of space as a separate entity from its content, influenced by it but in no way generated by it (his "spin network" concept tells all).
[69] For a "*closed time-like curves*" discussion and uncomputability in that case see Thorne (1994) and Penrose (1994) p. 382, where a reference to an unpublished paper by D. Deutsch is mentioned.
[70] As reported by Davies (1996) p. 218.
[71] The meaning of measurement has been debated for a long time. See Wheeler and Zurek (1983).
[72] D'Espagnat (1989) Part 3.
[73] See Einstein *et al.* (1935) and Schroedinger (1935).
[74] For an introduction see Green *et al*. (1987) and Hatfield (1992).
[75] Abbott (1988) p.106.
[76] See §16 of Einstein (1916). This translation needs corrections, so use also Einstein (1955) p. 82 and following.
[77] In the first appendix of Einstein (1955).
[78] Menzel (1953) p. 141 and 277 (or 384) for its definition in hydraulics and electromagnetism. The system can be dynamic even if closed. Poisson equation then leads to the gravitational wave equation, a feature Einstein did not consider critical for his theory.
[79] See Parts VI and VII of Misner *et al.* (1973).
[80] See Einstein (1955) p.112.
[81] Martinez (1999) gives a review of the matter.
[82] See Einstein (1955) p.110 and following.
[83] Lerner (1990) and Lerner (1992) p. 51.
[84] Hellemans (1997) admits: "the interplay between the accretion disk and the black hole *somehow* powers the outburst."
[85] See Sakurai (1994) for the conventional "quantum-mechanical way of thinking" (which really explains nothing).
[86] They show that indeed multiple realities can be observed.
[87] Bohm and Aharonov (1957) and Aharonov and Bohm (1959). Also described in Bohm and Hiley (1993). The phenomenon loses its mystique when analyzed through Feynman's path integral, see Schulman (1981) Chap. 23.

[88] See Penrose (1994) Section 5.3. This is an improved description of the original by Kochen-Specker as well as the one given in Peres (1993).
[89] As reported in Sakurai (1994) p. 129. Discussed in Section V.
[90] "Null measurement" in the present section covers this experiment.
[91] For a review see Chiao *et al.* (1995).
[92] von Neumann (1932) calls it "type 2 process."
[93] Dirac (1958) p. 108 footnote.
[94] This experiment teleports a coherent state of an electromagnetic field, but it could as well teleport a massive quantum (atom) state.
[95] I use this set-up to provide an easier description. The actual experiment used a Michelson interferometer, see Kwiat (1995).
[96] Due to their single speed and harmonic oscillator character, and as their path integral demonstrates, these realities will remain located within a classical trajectory (qualitatively, destructive interferences between photon realities eliminate any other path). See Feynman and Hibbs (1965) and Feynman (1985). In the case neutrons are used, other paths exist but only the one hitting the object and the one hitting the detector need to be considered. See last Remark at end of section.
[97] Hubble (1929). See also Longair (1996) pp. 104 and 126 and Elmore and Heald (1969) p. 165.
[98] The saturation area around the source is hypothesized to explain the observed rotation of galaxies as a *whole system in its own space*, obviating the need to postulate an unphysical "dark matter."
[99] As reported in Bahcall *et al.* (1999). See also Reiss *et al.* (1998) and Perlmutter *et al.* (1998).
[100] Longair (1996) p. 41.
[101] Astronomical objects such as Gamma Ray Bursts and Quasars have been found with redshifts up to at least 5 (Hjorth, 1999) corresponding to an age for these objects of *75 billion years* or more in the picture presented here, so the visible universe may be *a lot* larger.
[102] Which follow the path of "gravitons" in Particle Physics, another example of many unphysical concepts used in modern Science.
[103] In answer to the 1935 Einstein-Podolsky-Rosen quantum theory foundational question in Einstein *et al*. (1935). This question was designed to show that quantum theory, as developed since the 1920's, was in fact an incomplete theory for fully representing the physical world by using a statistical approach instead of a deterministic one. Everett's interpretation was reaffirmed under the name of "Many-Worlds" by DeWitt (1970a, 1970b).
[104] As formally defined by von Neumann (1932).
[105] Everett did not know about the process of *decoherence* discovered in the 1990s (Zurek, 1991) which reduces all the quantum realities to a single one. Yet his interpretation is still applicable to a composite quantum system that remains *coherent* throughout its evolution. The Universe is just not such a system.
[106] Next section will discuss the validity of such an approach.
[107] This inference is inspired in part from comments by Bohm. It is referred to as the "branch communication inference" in the next section, where it receives its support (Bohm and Hiley, 1993, Ch. 13).
[108] Menzel (1953) Part II, Sect. 39.
[109] Schwartz (1966), Ch. I, §1.
[110] Byron and Fuller (1992), Vol. 2.
[111] Cohen-Tannoudji *et al.* (1977), Vol. 1, Sect. J_{III}.
[112] A continuous observation makes the subsystems unseparable, and thus can only evolve together so the observer would not see ever a change in the observed system.