A Promising Model of Time

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1. Introduction

During the past century theoretical physics has become unintelligible for all but a few experts. Even the experts are quoted as saying no one really understands quantum mechanics. General relativity is understood, but is somehow wrong because it does not reconcile with quantum mechanics.

Perhaps as a result, attempts by well-respected physicists to interpret the universe have become downright bizarre. Serious consideration is given to whether or not the universe is a giant simulation or hologram. Perhaps it is one of an infinite number of alternative universes that are created every time and place a choice is made. These ideas have about the same metaphysical validity as the belief that an omnipotent god created it all.

When science proposes explanations that resemble religion it is time for Occam's razor to start cutting. Rather than extending and defending current theory we need to start looking for new theories based on different paradigms. Is there a basic concept, so far overlooked, that breaks through the complexity and offers more intuitive ideas of what the universe is and how it works?

Yes, there is at least one. It is a concept that can revolutionize physics even though it has been under our noses for as long as special relativity. Furthermore, it is sufficiently simple that anyone with an undergraduate degree in physics can understand it.

This paper explores the concept that time is a vector quantity rather than a scalar. Although physics texts often use the term "the arrow of time" to suggest that time has a fixed, irreversible direction, they then put that characteristic away and treat time as a scalar in all subsequent discussion. There is a reason for that. Treating time as a scalar makes the math much easier. Successful models can be built using scalar time for almost all of the dynamic events we humans observe.

But that success comes at a price. Treating time as a multi-dimensional vector quantity instead of limiting it to a scalar allows us to create models that fundamentally change our understanding of particles, forces, and reality itself. Unfortunately, physics has not yet explored these models. This paper is a baby step toward that end.

There is another reason why physicists have chosen to avoid treating time as a vector. Human perception is strongly biased against it. It is hard to imagine what multi-dimensional time even means. But it is not impossible to build a vector model of time, and doing so just might lead to some real progress in physics. This paper is offered in that spirit.

2. Preliminaries

We start by considering projection effects. What does an event that occurs in multi-dimensional time look like to an observer who can only perceive it in unidimensional time? Here are some examples.

Example 1:

Imagine a rod with a long axis of length L that is much greater than the rod's diameter. Place the rod so that this long axis is perpendicular to the line of sight between the center of the rod and an observer. Now spin the rod using this line of sight as the axis of rotation. Spin it so that it has a constant, non-zero angular velocity, $\frac{d\theta}{dt} = \text{constant} \neq 0,$ where θ is the angle of the rod in the plane of rotation and t is the time we are familiar with. Over some interval of t, the observer sees the rod sweep through all angles, $0 < \theta < 2\pi$, and then repeat this sweep. The observer sees the rod in motion and always perceives it as a rod.

Now imagine spinning the rod in multi-dimensional time rather than scalar time. Let the rod's angular velocity be a function of a component of time t' that is orthogonal to the time we are familiar with. In other words, $\frac{d\theta}{dt'} = \text{constant} \neq 0$, where t' is orthogonal to t, and $\frac{d\theta}{dt} = 0$. What does the observer see in this case?

The observer only experiences the t component of time and is unable to perceive t'. The rod's angular velocity is zero for the observer. She does not perceive the rod's rotation. But she *does* perceive the rod at all the angles it assumes during its sweep. Thus, the observer perceives a non-rotating disc with diameter L. This is simply a projection effect of the observer not being able to perceive motion that takes place as a function of t'. For the observer, effectively, that motion takes place instantaneously, blurring the location of the rod into a disc.

Example 2:

Next consider a particle moving along a closed path, a simple orbit for example. If the motion is strictly a function of t, then the observer sees classical orbital motion. But if the motion is only a function of t', the observer does not see any motion. Instead, she sees the particle spread out all along the path. She might conclude that the particle is a motionless loop, or a shell if its orbit is not confined to a plane.

Now imagine that the particle moves along its path as a function of both t and t'. The observer sees the motion that depends on t, but not the motion that depends on t'. This latter motion makes the particle seem spread out along a portion of its path. It might appear to be a "fuzzy" particle moving along the path as a function of t.

Some Convenient Terminology:

Before proceeding, it is convenient to coin a new term and establish some notational conventions. We want to discuss functions of time assuming that it is a multi-dimensional vector, but we also want to segregate out from this vector the component we are familiar with and can readily observe. We need a term for t' that identifies it as time-like but distinguishes it from t.

In the remainder of this paper we use the word "time" exclusively for t and coin the term *primetime* for t'. We define *primetime* as a three-dimensional vector (3-vector) that has three orthogonal components. We consider time to be a vector component that is orthogonal to *primetime*. *Primetime* combines with time to make up a four-dimensional vector (4-vector).

Functions of *primetime* and time, for example motion, are notated as $f(t',t)$ remembering that t' has three orthogonal components. Furthermore, $f(t',t)$ is itself a multi-dimensional vector, either a 3-vector or a 4-vector, and its components are orthogonal to both time and *primetime*. Hence, we are working in an eight-dimensional (8D) domain where (t',t) comprises four of the dimensions and $f(t',t)$ ranges over either three or four of the other four dimensions.

To discuss particle motion we define a point's position in three-dimensional (3D) space as a 3-vector function of (t',t) notated as $P(t',t)$. Spherical coordinates (r, θ, φ) are used in the example below so that the motion of a point in 3D space is described by the equation (r, θ, φ) = $P(t',t)$.

Example 3:

Assume that P is not a function of time and varies over *primetime* such that θ ranges between 0 and 2π, φ ranges between –π and π, and r ranges between 0 and r_0. In other words, our point moves through all the 3-vectors (r, θ, φ) that are elements of 3D space and that have $r \leq r_0$. It then repeats that motion.

An observer who does not perceive *primetime* also does not perceive the point's motion. Rather, she perceives the point as if its motion happened instantaneously. She perceives a continuous, spherical volume with a radius of r_0 rather than a dimensionless point sweeping out that volume.

Discussion:

This observation, the observer's perception, is a physical process that takes place in time and does not experience *primetime*. There is no reason to treat human perception as somehow especially different from other physical processes. Any process that is a function of time and not *primetime*, whether or not human consciousness is involved, will interact with our moving point as if it were a sphere. That the point appears to be a sphere is not an illusion. It is a projection effect that results from the "observing" process being strictly time-based and independent of *primetime*.

Furthermore, this projection effect is not limited to a process in time that "observes" a process in *primetime*. It also occurs between processes that are functions, separately, of any two of the orthogonal components of *primetime*. If $\varphi = P_1(t'_1)$, $\theta = P_2(t'_2)$, and $r = P_3(t'_3)$, where subscripts have their usual meaning, then P_2 "sees" all of P_1 and P_3 instantaneously, P_1 "sees" all of P_2 and P_3 instantaneously, and P_3 "sees" all of P_1 and P_2 instantaneously. In other words, r changes over t'_3 as if P_1 and P_2 exhibit their entire range of values simultaneously and do not vary. Similar statements hold true for θ and φ.

An important consequence of this is that P does not have to be a very complicated function to range continuously over all the points in 3D space where $r \leq r_0$. The simplest case is a set of parametric equations where each orthogonal component of P is a function of a single, orthogonal component of *primetime*. The components of P might depend on multiple components of *primetime*, but that makes P a more complicated function. The math and physics get much harder. Things get "fuzzy".

Of course, motion is not the only physical characteristic we are interested in. Return to Example 1 above, the spinning rod, and consider what else might be observed.

Assume the rod has constant density along its length. For time-based processes that "see" it as a disc, the rod's mass at each point of its length appears to be spread out into a circle. The disc's density appears to vary inversely with distance from a maximum value at the center of the disc to a minimum value at its edge.

Another projection effect gleaned from Example 1 is that time-based processes detect the disc's non-zero angular momentum, even though its angular velocity appears to them to be zero.

Now reconsider Example 3, the point that sweeps out a spherical volume in *primetime*. If the point carries physical attributes, for example density, charge, or charm, a time-based observer "sees" these spread out over the volume. Exactly how these attributes appear to be distributed depends on the details of $P(t')$.

Example 4:

All the examples above are limited to motion that is both bounded and periodic. Now consider a particle moving along an unbounded and open path as a function of *primetime* only. What does a time-based observer see?

Since the path is open and unbounded, an observer is not likely to observe the entire path all at once. She usually looks for the particle in some portion of the path at some specific time. Because the particle's position is not a function of time, where a time-based observer finds it is random. If the particle happens to be in the portion where she looks, the observer sees the particle. But if it isn't, she doesn't.

If she looks repeatedly, she might see the particle some percentage of her observations. If her preconception of the observation is that the particle moves along the path as a function of time and her job is to determine that function, she might conclude that the function can only be determined as a probability. But since the particle actually moves only as a function of *primetime* and not time, what she has actually determined is some measurement on the act of her observation itself, not on the motion of the particle.

In other words, because the observation takes place in time, the observer forces a time dependency on where the particle is or isn't found. This dependency on time, by definition, is not an inherent part of the particle's motion. Rather, it is a projection effect caused by the observation. The act of observation doesn't change how the particle actually behaves *a priori*. Rather, it affects how the particle appears to behave *a posteriori*.

Now consider the particle's motion to be a function of both *primetime* and time. In this case the observer can gain an approximation of where the particle is at various times, but cannot determine its location precisely. A suite of observations might lead to a probabilistic prediction of where the particle is to be found as a function of time. The probability distribution of the particle along its path might even be determined as a non-empirical formula. Because that probability is related to the integral of the *primetime* part of the position function $\mathrm{P}(t', t)$, this formula provides information about how the particle's motion depends on *primetime* as well as time.

The reader familiar with modern physics might now appreciate that treating time as a vector offers great potential for understanding the peculiarities of quantum mechanics. We return to this topic in section 9, but first we need to address a critical question related to macroscopic physics. If time is truly only one component of a multi-dimensional vector, why is that fact not seen in our day-to-day lives? The next two sections introduce one possible answer.

3. Much Ado About Nothing

With an apology to Shakespeare, we digress briefly into metaphysics to remember that there is a distinction between mathematics and physical existence. The two are not identical. Mathematics exists in a conceptual realm. It is *a priori* truth and is independent of physical existence. Hence, math can be used to describe and model the absence of physical existence as well as the universe we exist in. We can use it to model absolute nothingness which we label "nothing". Doing so, we reach some pretty exciting conclusions about "nothing".

We begin by using a vector space, a mathematical construct, to examine a hypothetical universe that consists of absolutely nothing. This universe does not even include physical space-time. The vector space we will use is the 8D domain introduced in the terminology subsection in section 2 above. It includes axes labelled "space", "*primetime*", and "time", but these are there to represent potential aspects of the universe and not its initial conditions. We model "nothing" as a dimensionless point at the origin of 8D and apply perturbation theory.

Imagine an infinitesimal displacement of our point in the 3D space portion of 8D. Let this displacement exist as a function of a 3-vector in the *primetime* portion of 8D. In other words, imagine an infinitesimal change in $P(t')$. Let this displacement be closed and bounded, for example a vibration about the origin. Then, as we learned in Example 3 (section 2) above, a projection of this displacement will occur on the time axis of 8D. A projection or "ghost" of the displacement will seem to persist for some infinitesimal interval of time and will have the appearance of a 3-dimensional volume of space. Perturbations in $P(t')$ create "ghost" volumes of space for instants of time.

It is the inclusion of *primetime* in our vector space that leads to this phenomenon. Moreover, *primetime* does not have to be a 3-vector for it to occur. An 8D vector space was used for a special reason that will be discussed later, but these virtual bubbles of space-time emerge in 5D, 6D, and 7D as well.

We conclude from this that any universe that includes the potential for both space-time and *primetime*, but whose initial conditions are "nothing", is inherently, mathematically unstable at those initial conditions. Exact nothingness is an existence that instantly diverges from equilibrium. Space-time bubbles appear to pop into and out of existence. We see the same instability at quantum scales in our current physical universe. The "vacuum" is filled with "virtual" bubbles of existence called quantum fluctuations.

But here is the important and truly astonishing conclusion:

By the anthropomorphic principle our universe must have had the potential for 4D space-time at its initial conditions. We only have to add the potential for *primetime* to this to get a whole lot of something from nothing. To get from "nothing" to our current universe we do not need to inject a huge quantity of energy instantaneously into our dimensionless point. We do not need a "big bang". We only need *primetime* and a way to turn that sea of virtual space-time bubbles into a real one. One way this might happen is described next.

4. Space-time

Reconsider a physical universe that is absolutely empty of anything. There is no matter or energy. There is no space or time. Nothing exists at all. Although these initial conditions are certainly hard to fathom, this is the state at which the most widely accepted cosmological theory of today, the Big Bang Theory (BBT), begins.

BBT's infamous "singularity" involves an instantaneous step-function from this state of complete nothingness to a state where everything, all the matter and energy of our current universe, plus space-time itself, exists as a compressed, infinitesimally small volume-instant. In BBT time begins (is zero) at the step-function then increases as a scalar. As time increases, all matter and energy, woven together with an expanding volume of space-time, evolves through various states until our current physical universe is reached.

This aspect of BBT, that everything instantaneously came into existence compressed into a volume even smaller than quantum scales, intuitively seems unlikely. Alternatively, an 8D vector space that includes *primetime* allows us to construct a smoother, intuitively more plausible process that also produces our current physical universe from nothing.

Hypothesize a particle with certain special attributes. These attributes are grouped into its state properties, its decay properties, and its exclusion properties. For ease of reference we will name this hypothetical particle the *realton*.

We define the *realton* to have two states, a ground state and an excited state. In its excited state it conveys a 6D vector space to its location. This 6D vector space is the union of 3D space and 3D *primetime*. The *realton* is continuous and bounded in both space and *primetime*. These bounds on space and *primetime* are small even on quantum scales. Note that time is not present in this definition. The excited state of the *realton* does not persist in time. Rather, it persists in *primetime*. The *realton* exists independently from time.

The ground state of the *realton* simply consists of a dimensionless point in 6D space-*primetime*. For the realton in its ground state, 3D space equals (0, 0, 0) and 3D *primetime* equals (0, 0, 0). Again, time is not present. An observer or other process limited to time might observe a *realton* as being in both states, ground and excited, simultaneously. The excited state would appear to be a static 3-dimensional extent or volume of space.

The apparent shape of this volume that a time-based observer observes depends on how 3D space varies as a function of 3D *primetime*. Recall the position function $\mathrm{P}(t')$ that we defined earlier. Using it to model this relationship, we consider the shape of the *realton* at the end of this section. For now, we can just assume it is spherical.

The next key attribute of the *realton* is that its excited state decays into decay products. We define the decay products of the excited *realton* to be multiple new *realtons* also in the excited state. For example, we might assume that two (or three) new *realtons* result from the decay. The first *realton* transitions back to its ground state, which does not convey 6D space-*primetime*, and is replaced by two (three) new excited *realtons* which do convey 6D space-*primetime*. Of course, the two (three) new *realtons* also decay to produce four (9) excited *realtons*, then eight (27), and so on.

We might think of a *realton* as being "real" only if it is in its excited state. A *realton* in its ground state might be called a "virtual" particle. When a *realton* transitions from its ground state to its excited state, it emerges from a "virtual" realm into reality, exists for a while, and then returns to the "virtual" realm, leaving behind multiple excited *realtons*. This begins an infinite sequence of decay generations that produce an exponentially growing cluster of *realtons*.

We complete our definition of the *realton* by requiring it to obey an exclusion principle. No two *realtons* can occupy the same excited state. They cannot occupy the same space and *primetime*.

This means that the small bits of 6D space-*primetime* conveyed by *realtons* do not overlap. They can, however, be adjacent. Indeed, by definition they must be adjacent. There is no space between *realtons* since space is conveyed by *realtons*. Any gap or space between two *realtons* would only exist if there were *realtons* there as well.

Given this definition of the *realton,* consider what happens if it actually exists. Once one *realton* transitions to its excited state, the number of *realtons* grows exponentially. These *realtons* aggregate and the total volume of 3D space conveyed by them also grows exponentially. If this cluster of *realtons* is a universe, that universe expands.

In the first few decay generations *realtons* easily satisfy the exclusion requirement. They simply replace and add layers of space to the volume of space conveyed by the previous generation. The aggregated volume of space expands in a purely space-like way.

After a few generations, however, the *realtons* in the center of the cluster are surrounded by other *realtons* that are also decaying. When one decays, it can replace itself with one of its decay products but must compete with surrounding *realtons* to add any new *realtons* to the cluster. There are no unoccupied adjacent states in 3D space into which *realtons* can deposit their decay products.

This causes exclusion pressure to develop. Once all the adjacent spatial states are filled, exclusion pressure forces *realtons* to deposit some of their decay products into adjacent temporal states. But these temporal states are not *primetime*.

Primetime does not aggregate like space does. It combines in a different way to create temporal states that exist adjacent and subsequent to the previous generation of *realtons*. Exclusion pressure forces *realton* decay to deposit new *realtons* into the same spatial location that others have but at a different time, an adjacent and later time. Exclusion pressure is relieved by the creation of time as we know it.

There is no time as we experience it when the universe begins. The first phase of the universe happens without time being there as a governing metric. It happens exclusively in *primetime*.

The second phase of the universe begins when familiar time is created, and subsequently re-created continuously, by *realton* exclusion pressure. Time is orthogonal to both *primetime* and space. This results in both the continuity of time outside the *realton* and the persistence of space within time. As a consequence the expansion of space is correlated with an increase in time. But the expansion of space is not a function of time. Rather, both these phenomena are results of the same underlying cause.

Time as we know it emerges from the same process that causes space to expand, *realton* decay and exclusion pressure. It emerges continuously throughout the universe except at the very outermost fringe of the universe. Here, the absence of adjacent *realtons* permits *realton* decay to expand 3D space without generating time. At the edge of our universe, time has not yet come into existence.

Exclusion pressure is not relieved by the creation of time alone. Spatial expansion continues throughout the universe not just at its edge. A balance or equilibrium forms between these two release mechanisms. An observer in our current universe sees both spatial expansion and the passage of time throughout the observable universe.

To summarize then, the universe starts as the state transition of a single particle (a *realton*) with certain properties. It then expands to a critical size by spatial accretion without the passage of time. Once it reaches this critical size, exclusion pressure causes it to expand in a time-like way as well. Time as we know it begins. Equilibrium is reached between exclusion pressure and expansion. Subsequently, the universe ages along a timeline while it continues to expand. *Primetime*, confined to the sub-quantum scale of the *realton*, is not easily observed. Certain projection effects of *primetime* are experienced by time-based processes at quantum scales, but not at macroscopic scales. All of this happens because of the properties of the *realton*. No other *ad hoc* conditions are required.

If time emerges in the way described above, it must have a dependency on *primetime* even though it is orthogonal to *primetime*. We conclude that time is some function of the cross product (also called the inner or wedge product) of the three components of *primetime*. This can be written as

$$t = f(t'_1 \times t'_2 \times t'_3).$$

Now we can give the reason why 8D is the right dimension for modeling our universe.

With exactly two exceptions, the vector cross product only exists in the vector space that has a dimension one greater than the number of vectors being crossed. The cross product of two vectors exists in 3D, the cross product of three vectors exists in 4D, the cross product of four vectors exists in 5D, and so on. However, the cross product of two vectors does not exist in 4D. This can be seen intuitively by remembering that in 4D there are an infinite number of directions that are perpendicular to the plane defined by the two vectors being crossed.

One might conclude that the cross product of n vectors could never exist in a vector space with dimension greater that $n + 1$. However, mathematics permits two, and only two, exceptions. The cross product of two vectors exists in 7D, and the cross product of three vectors exists in 8D. Furthermore, the cross product of three orthogonal vectors in 8D is the same vector as the cross product of those three vectors in 4D.

Specifically, if $(t'_1) \times (t'_2) \times (t'_3) = (t)$ is true in 4D, then $(t'_1, 0, 0, 0, 0) \times (t'_2, 0, 0, 0, 0) \times (t'_3, 0, 0, 0, 0) = (t, 0, 0, 0, 0)$ is also true in 8D. This characteristic is unique to 8D. Hence, it is the only vector space that permits *primetime* to co-exist with time and space.

Earlier in this section we stated that the *realton* in its excited state "conveys" 3D space to its location. Assuming that time emerges from *realton* decay and exclusion pressure we can now consider what it means to convey 3D space.

A point moving in accordance with a position function $P(t')$ creates the appearance of a persistent volume of space to a time-based process as long as $P(t')$ sweeps out some bounded region of 3D space. There are many functions $P(t')$ that have this necessary characteristic. If the excited state of the *realton* can be modeled by such a position function then perhaps the *realton* is actually only conveying the appearance of a volume of space to any and all time-based processes. Macroscopic physics operates as if a volume of space is there, but perhaps space is actually a projection effect of a process that is occurring in *primetime*.

Consider what that process might be. One possible $P(t')$ that might model the process is a vibration or pulse that propagates outward from a point as a three-dimensional standing wave and then dissipates when the *realton* decays. The characteristics of this wave, its frequency, amplitude, and waveform shape, depend on the details of $P(t')$. Since *primetime* has three independent and orthogonal components, a *realton* can adopt various position functions $P(t')$ to produce many different standing waves when it transitions to the excited state. The transition might occur when a quantum of energy is absorbed, with $P(t')$ depending upon the exact amount of that energy. Note that this model is not very different from modern string theory.

5. Particles, Energy and Matter

Up to this point we have not mentioned matter or energy. What we have done is introduce a mechanism for the generation of 4D space-time from nothing. The space of the universe is the accreted space conveyed by a cluster of *realtons*. Time is not an *a priori* component of the universe but is the product of *realton* exclusion pressure.

But the universe contains more than space-time. What about matter and energy? To answer that question we consider *realton-realton* interactions.

Assume that a *realton* conveys space via a standing wave in 6D space-*primetime*. This wave is the combination of three independent waves on each of the axes of 3D space that are functions of each of the three components of *primetime*. When a *realton* transitions to its excited state it adopts a standing wave selected from a spectrum of possibilities. This means it takes on a specific waveform or shape in 6D space-*primetime*.

[Aside: Perhaps only some excited *realtons*, those that excite into the right shapes, convey space. However, this possibility does not change the basic ideas presented here. At least a portion of excited *realtons* convey space. That is all that is needed. Another question worth exploring is if the *realton* has more than one excited state. This would complicate the picture, but not fundamentally change the nature of space-time.**]**

Adjacent *realtons* interact when they try to deposit their decay products into the same space. The vast majority of these interactions are incoherent. The standing waves of the *realtons* involved are not in phase. Because of exclusion pressure, incoherent interactions produce decays into adjacent temporal states. The majority of *realton* interactions just contribute to generating time.

But occasionally *realtons* interact coherently. By coincidence the waves are in phase and combine constructively or destructively. The combined wave is no longer a *realton*. The interacting *realtons* have merged into something else. It does not convey space-*primetime* nor does it decay into new *realtons*. It is a new, different particle with its own properties. Since *realtons* have various waveforms several different types of particles can result when they merge.

Most of these particles rapidly decay into quanta of energy. These quanta are immediately re-absorbed by an infinity of unexcited, ground-state *realtons* that exist virtually within the cluster of excited realtons. The result of this re-absorption is additional excited *realtons* and an acceleration in the rate of expansion of our universe. This process accounts for “dark energy”.

There is also a small subset of coherent *realton* interactions that merge into solitonic waves. These do not decay immediately but persist as particles. Again, since they are not *realtons* they do not convey space. But since they are surrounded by *realtons* they appear as point-like objects that occupy a position in space.

Similarly they do not convey *primetime*. But because the *realtons* around them are generating time they also experience time and persist in it. These persisting particles have various wave characteristics and therefore various physical properties. These properties influence the surrounding *realtons* in various ways.

In summary then, *realton* interactions not only generate 4D space-time, they also generate “dark energy” and a suite of point-like, “fundamental” particles that are embedded in 4D space-time. Subsequent interactions between these particles create other, more complex particles that incorporate a matrix of *realtons* and therefore do have extents in 3D space.

Interactions between *realtons* with a specific waveform might result in the creation of a specific type of quark. Other waveforms might result in the creation of other types of quarks or the various types of leptons. Once we have quarks and leptons, these fundamental particles interact to generate all known matter. At least, this happens if the fundamental forces are present.

6. A Quark Field and the Strong Force

In the preceding section we hypothesize that quarks and leptons are solitonic particles created when *realtons* with certain specific waveforms interact coherently. It should be emphasized that these waves occur in *primetime* and not time. Quarks and leptons persist in time but the action inside them, the solitonic wave, happens in *primetime* only. It is not apparent in time. Time-based processes “see” this action as if it were instantaneous.

We also suggest that quarks and leptons influence the *realtons* surrounding them in various ways. This influence is also a function of *primetime*. Because the *realtons* surrounding a quark or lepton are constantly replacing themselves as well as generating time, the influence of a quark or lepton on its surrounding *realtons* persists in time just as the quark or lepton does.

The nature of the influence might be any combination of the several possible ways a *realton* can change. Primarily, these are changes to the *realton's* standing wave such as changes to its waveform, frequency, and amplitude. All these are functions of *primetime*.

If quark influence changes the frequency or amplitude of a neighboring *realton's* standing wave that wave is disrupted. The *realton* transitions back to its ground state without decaying into new *realtons*. It disappears.

This happens to all the *realtons* in a shell surrounding the quark. The spatial states these *realtons* occupied become vacant. The *realtons* in a shell just outside of the disappearing shell can deposit new *realtons* into these adjacent vacant states. Of course, these new *realtons* are disrupted by the quark as well. The consequence is that *realton* exclusion pressure is lowered around the quark and this reduction persists in time.

Reduction of *realton* exclusion pressure extends outward into a spherical volume centered on the quark. The amount of the reduction diminishes with increasing radius until at some distance a from the quark the reduction is zero and an equilibrium value for exclusion pressure is reached. For convenience, we call this spherical volume the quark's aura. In some ways this aura is analogous to a field.

Now consider two quarks that both have an aura with radius a. If they are close enough for their auras to overlap there is a lens-like volume between the quarks where the *realtons* feel the influence of both quarks. Inside the lens the two influences combine to further reduce exclusion pressure. It becomes lower than if only one quark was influencing the *realtons* there. We might think of the lens as a low pressure zone inside the combined auras.

Let the two quarks approach each other from a distance. More precisely, let the quarks have a relative motion as a function of time such that their line-of-sight separation d steadily diminishes. While the quarks are farther apart than two times the radius of an aura, $d > 2a$, the auras do not overlap. The lens has not formed.

Now let the auras touch and then overlap slightly. The lens forms and a small low pressure zone is created. As the quarks continue to approach each other their auras overlap more. The lens of low pressure increases in volume. It encapsulates more *realtons*. Because those *realtons* are closer to the quarks, the low pressure zone deepens. The pressure lowers. This trend continues as the separation decreases within the range $2a > d > a$.

In this range, relative motion that decreases quark separation results in a reduction of the total exclusion pressure in the lens. Relative motion that increases quark separation increases total exclusion pressure. That means potential energy is reduced by motion that decreases quark separation. The quarks accelerate towards each other. There is an attractive force $\mathbf{F}(d)$ between them.

However, as quark separation continues to decrease, entering the range $a > d$, the volume of the lens becomes comparable to the volume of an aura. At small quark separations the distances between most *realtons* and the quarks are larger than d and do not change much as the quarks move. Therefore the influence of the quarks on most *realtons* inside the lens changes little while they move. Quark motion no longer changes the total exclusion pressure by much. The quarks no longer experience a potential slope. More precisely, this slope approaches zero. The force between them, **F**, decreases to zero. The quarks can move about relatively freely.

In summary then, two quarks at a separation $d > 2a$ do not feel the force **F**. If their separation is in the range $2a > d > a$, they feel **F** as an attraction that increases with decreasing separation. If their separation is in the range $a > d$, **F** decreases toward zero as the separation decreases. When two quarks approach each other they become "confined". Their separation must remain less than a value that is somewhere between a and $2a$. But as long as their separation remains under a value that is somewhere less than a they experience "asymptotic freedom".

Two quarks that reduce the *realton* exclusion pressure around them, perhaps by inducing a frequency change in the standing waves of those *realtons*, generate and respond to a potential energy well that looks very much like the strong force. If we start with a quark and its paired antiquark we produce a meson.

The meson comprises two quarks separated by *realtons*. It also incorporates the cloud of *realtons* influenced by these quarks, their auras. Unlike the point-like quarks the meson has spatial extent.

Since a quark has different aura characteristics than its antiquark, a different a for example, we need to take this into account when we actually try to model a meson. If we want to model a baryon we must consider a three-body quark interaction. That is certainly more complicated than the simplified two-body model described above. Finally, a complete model of a hadron must also include the other fundamental forces.

7. Other Forces

In the previous section we explain how the strong force results from quarks disrupting the normal decay of the *realtons* surrounding them. It is likely that the other fundamental forces are also caused by the influence of quarks and leptons on surrounding *realtons*. For example, potentials that depend on the inverse square of distance might emerge from an influence on *realtons* that modifies their waveforms without disrupting them.

One such waveform modification is frequency modulation. In this case *realtons* act as signal carriers with signal strength falling off in the prescribed manner. To an observer unaware of the wave physics going on in 6D space-*primetime*, the signal appears to be a field generated by the quark or lepton. Other quarks and leptons also create frequency modulations in the standing waves of the *realtons* surrounding them. These signals combine to create apparent forces between quarks and leptons.

Fuller descriptions of these processes remain to be developed.

8. Entropy

We now re-examine the *realton* to understand another critical consequence for the universe, entropy.

The *realton's* state characteristics comprise a virtual ground state and an excited state that conveys 6D space-*primetime* to its location. This implies that 3D space is quantized. At sub-quantum scales space is not the absolutely smooth concept of space that comes from mathematics. It is an aggregation of individual interacting particles, *realtons*.

Each excited *realton* conveys some fixed amount of space and that space only exists within the *realton*. There is no gap, no space, between *realtons*. Their exclusion characteristic prevents *realtons* from occupying the same space. They must form an aggregate.

Since an excited *realton* can take on any one of a suite of possible standing wave geometries in 6D space-*primetime*, the size and shape of adjacent *realtons* vary and so the way they pack together into an aggregate varies. For example, an aggregate consisting of *realtons* of the same size and shape (including orientation) might pack together like a crystal. Aggregates comprising a random distribution of *realton* size and shape pack into a conglomerate.

Realtons constantly decay into new *realtons*. In addition to creating time from *primetime*, generating dark energy from coherent wave interference, and spawning leptons and quarks from solitonic wave interference, *realtons* are constantly and randomly repacking themselves. This latter process results in entropy. The entropy of space is the degree of randomness that the *realton* aggregate has reached.

Increasing the entropy of space is yet another way the aggregate of *realtons* relieves exclusion pressure. If *realtons* were somehow forced to remain in a crystalline configuration, they would find it harder to decay into adjacent states because these would be restricted by the lattice. In a conglomerate configuration, adjacent states are more readily available. The more random the configuration, the easier *realton* decay becomes and exclusion pressure is relieved.

Realton decay and exclusion pressure tend to increase the randomness of the aggregate's packing configuration thereby increasing its entropy. *Realton* packing happens together with aggregate expansion. The increase in the total number of *realtons* also increases total aggregate randomness and entropy.

It should be emphasized that entropy increase is not a function of time. Entropy increase and the advance of time are two independent effects of a single, shared cause, exclusion pressure. They are correlated but neither is a function of the other.

Entropy is analogous to time in some striking ways. Just as time always increases so too does entropy. Just as time emerges from *primetime* to relieve exclusion pressure so entropy emerges from space. Just as time is a function of the cross product of the three orthogonal components of *primetime*, entropy is related to the three dimensional volume of space.

These characteristics suggest that entropy is a good candidate to be the eighth component of the 8D vector space we have chosen to model the universe. An increase in entropy includes both an increase in the number of *realtons* in the aggregate along with the change from a regular crystalline configuration of *realtons* into a more and more random conglomerate configuration.

This implies that the *realton* aggregate was more crystalline in the early stages of the universe than it is in the current epoch. Intuitively, this seems reasonable. The earliest generations of *realton* decay might have preferentially produced the same 6D standing wave geometry. After the universe evolved through its initial expansion, *realton* decay might have started producing a greater variety of *realton* sizes and shapes. The further increase in aggregate volume would then have increased the number of ways those sizes and shapes could pack together.

This progressive change into a less crystalline configuration would also change other characteristics of the aggregate. For example, the permittivity of space would increase and hence the vacuum speed of light would decrease. This would have observable consequences for our universe.

Consider the journey of a photon generated in the early universe and reaching our eyes today. It starts with a higher speed than light travels at today. While it travels along its path its speed decreases due to the increase in the entropy of the space it encounters. After billions of years we detect it travelling at the currently measured value for the speed of light. Because the photon has slowed, we also see its wavelength red-shifted.

The farther the photons we detect have traveled the more they are red-shifted by entropy. This red-shift is added to the red-shift caused by the expansion of space and makes that expansion appear to be accelerating. The acceleration we measure today might be due in part to the increase in entropy over the distance (and time) we are looking across. This might result in our overestimating the role dark energy plays in producing the acceleration.

9. Quantum Mechanics Redux

There are many reasons why theoretical physicists should rework modern physics with time treated as a vector rather than a scalar. One of the most compelling is the potential for developing a comprehensible interpretation of quantum mechanics (QM).

The Copenhagen interpretation of QM is strongly supported by experiment and is generally considered the most plausible interpretation available. It is based on the idea that the act of observation somehow causes many QM processes to assume specific states, and that these processes would remain a superposition of probabilities in the absence of observation. Physicists call this the collapse of the wave function, referring to Schrödinger's equation.

This is regarded by many as philosophically unsatisfactory. It would be preferable for physical processes to be independent of observation and for existence to be deterministic. The question arises whether or not QM is a complete theory.

This quandary is resolved if we recognize that QM processes can be functions of *primetime* and remember that the act of observation is a process that takes place in time. As we discussed in section 2, the time-based observation of a process that occurs in *primetime* forces a time dependency on that process which is otherwise not there. This forced time dependency is what we perceive as the collapse of the wave function.

The observed quantum process appears to be probabilistic rather than deterministic because we don't observe the whole process. Treating a *primetime*-based process as if it were time-based is an incomplete observation that usually results in a projection effect. If we had accounted for *primetime* when making the observation, the quantum process would appear deterministic.

Wave-particle duality is explained similarly. A lepton is inherently a wave phenomenon that is a function of *primetime*. Because leptons persist in space and time they can be observed by time-based processes. When that happens a time-dependency is forced upon them, the wave function collapses, and a projection effect is perceived. The *primetime* wave appears to have happened instantaneously to the time-based process of detection. The lepton appears to be a particle to the detector.

Recognize that *primetime* is not a "hidden variable" that Bell's inequality rules out. The argument from Bell's inequality is based on an implicit assumption that a hidden variable is a function of scalar time. Since *primetime* is orthogonal to time the argument from Bell's inequality does not apply to it.

"Spooky action at a distance" is now easily understood. The collapse of the wave function of two entangled particles separated by a large distance does happen instantaneously without any signal between the particles. A time-based observation of any part of a system of entangled particles causes a projection effect to instantaneously happen system-wide. There is no transmission of information across the system. A subset of the information that is already inherently there throughout the system is projected onto the time axis. Because a single time "creates" this subset it is the same at all locations within the system. Because the subset appears to be new information to the time-based observer, she might assume new information has propagated across the system. But as we have seen that is just a chimera. The information was there all the time but part of it remained hidden in *primetime*.

Now consider the Heisenberg uncertainty principle. In section 2, we state that motion that is a function of both time and *primetime* appears to be spread out to a time-based observer. This makes it impossible for an observer to determine both position and momentum with absolute precision. However, there is a much more fundamental basis for the uncertainty principle.

We state in section 8 that space itself is quantized. This means that the time-based velocity of a moving particle is also quantized regardless of how continuous time is. Neither position nor momentum can be determined with absolute precision. A point moving through the *realton* aggregate will never be closer than the width of a *realton* to where it was the instant before. Using Heisenberg's formula then suggests that the scale of the *realton* is approximately 7×10^{-18} meters.

10. Summary and Afterthought

This paper claims that time is not a scalar and must be treated as a vector quantity. Doing so allows us to develop new models of our universe that provide deep, intuitive insights about the physics of the universe and its components. Our construct of *primetime* might be the basis for an approachable interpretation of QM. The simple *realton* not only avoids a cosmological singularity, it promises an intuitive explanation of fields and forces.

Obviously this paper falls far short of adequately developing these models. It barely describes them at a topmost conceptual level. Much work is needed to rigorously develop and test these models and many other alternative models that are also based on multi-dimensional time. It is hoped, however, that this paper does successfully make the case that that work will be worthwhile.

In section 4, we describe the *realton's* ground state as "virtual" and its excited state as "real". Perhaps this distinction is a metaphysical delusion. Absolute nothingness is mathematically unstable in 8D. Perhaps it only exists as a concept in mathematics. Perhaps in the real universe nothingness is replaced with virtual existence and our metaphysical definition of reality must be revised to include the virtual realm. We might come to realize that nothingness cannot exist except as a useful mathematical construct.

The logical extension of this thought is that, given the unique characteristics of 8D, our universe is inevitable. The universe *had* to start and evolve in 8D. The "first cause" of our universe was mathematics, an *a priori* truth.

It might seem difficult to conceptualize a universe based on time being a vector. But remember that this is only important at quantum and sub-quantum scales. It is difficult to conceptualize the universe at these levels anyway. Fortunately mathematics still applies. It is available to help develop a new physics based on this paradigm. This new physics might just be easier to understand than the one we're grappling with now.