A Model for Constructing the Physical Universe

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Abstract

In the introduction I argue that the basic *element* (or primitive) for constructing the physical universe is "displacement from a prior level", and the basic *structure* is "a sequence of such displacements" (summarized as postulates 1 and 2). The displacements are then defined as one-dimensional objects with a direction (postulate 3). The relations between these displacements are stated in postulate 4.

In section 2 we discuss basic consequences of the postulates, and in section 3 we use the postulates to derive a (3+1)-dimensional structure, interpreted as ordinary space and time. We then derive further properties of space --- isotropy, homogeneity, and a rapid early expansion (i.e. inflation). Time, comporting with experience, is shown to be a one-dimensional *stream* --- with a direction.

In section 4 we associate *energy* with the displacements, and find that the same factors that construct ordinary space (and make it isotropic and homogeneous) also smear the locations of entities/particles across that space --- thereby providing a mechanism/explanation for that iconic and enigmatic aspect of quantum mechanics. We also determine that there must be a continual, uniformly-distributed *stream* of (non-zero-point) energy coming into the system that constructs new space (i.e. dark energy).

The streaming natures of both time and dark energy are shown to have the same basic cause: the *processes* that input dark energy into the system, and that construct time, are themselves *independent of time* --- and so they are *continual* processes.

Further consequences follow from the model, including an explanation for *why* the presence of energy affects space and time, and why quantum vacuum energy is an exception to this rule (i.e. does not gravitate) --- thereby eliminating the cosmological constant problem.

A key benefit of the model is that it liberates us from always having to think about the construction of the universe in terms of *spatio-temporal* relations and evolution (e.g. the big bang model), which is problematic because presumably (and as we will indeed see) space and time are *products of* the fundamental construction process, not things that govern it.

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1 Introduction

Systems that are based on *information* typically contain a basic information *element* and a basic information *structure*. In Biological systems, for example, the basic information element is the nucleotide molecule, and the basic information structure is a *sequence* of nucleotides (e.g. a codon, or a gene). Likewise, for computer systems (i.e. digital electronics) the basic information element is the bit, and the basic information structure is a sequence of bits (e.g. an 8-bit byte). And in natural language the basic information element is the letter or phoneme, and the basic information structure is a sequence of letters or phonemes (e.g. a word or a sentence).

Such systems must also have a way of translating or computing the information elements and structures into meaningful output. In biology this is accomplished by the operations of ribosomes, enzymes, etc., acting on the nucleotide strings. For computers, the operations of logic gates on the bit strings, along with the operations of control structures, typically perform this function. And in natural language the operations of lexical analysis, parsing, and context translate a string of letters/phonemes into meaning.

It may also be that the *physical universe* itself is based on information/computation of some sort. If so, then the following questions presumably become paramount: (i) What is the basic information element for the universe?; (ii) what is the basic information structure?; and (iii) how are these elements and structures translated (or computed) into the meaningful output that we call the physical universe?

Although many have speculated about an informational (or computational) basis to the universe (e.g. [1], [2], [3]), no one --- to my knowledge --- has yet proposed a concrete model that includes answers to the above questions. This paper aims to correct that deficit. Indeed, the following reasoning suggests answers for questions (i) and (ii) above.

Consider two states, A and B, where B represents the state that we find ourselves in right now, in which all of the things of the universe exist (i.e. space, time, particles, dark energy, etc.); and A represents a state that is ontologically *prior* to B, in which *none* of those things exist.

Note that A's *ontological* priority to B means that A is *independent* of B, but B is *dependent* on A (see [4]). Thus the creation of B cannot affect A; i.e., A still exists, and is unchanged. This is in contrast to the more conventional notion in which, implicitly at least, the state A (whatever it might be) is only conceded to be *temporally* prior to B, so that the existence of B supplants or replaces A, or at least A becomes irrelevant or ignorable once B is created (e.g. the big-bang temporal evolution model). In the present model, A's *ontological* priority means that it *stays* operant and relevant (this will be elaborated in section 2).

So, starting with state A, something presumably happens to create state B. To estimate what that something is, we ask the following question: In the simplest possible terms, what is the basic difference between states A and B? Answer: In some sense, state B is *displaced* from state A; for, if B were *not* displaced from A, then B would be the *same* as A, and none of the stuff of the known universe would exist. This leads to the following simple idea: The basic element for creating the universe, and the basic information element, is *displacement from a prior state*.

Now, just as you can't get much from a single bit, or a single nucleotide molecule, or a single letter/phoneme, so also you probably can't get much from a *single* displacement from a prior state. This suggests that the basic method for creating the universe (i.e., the method for creating state B, starting from state A) is a *sequence* of displacements from prior states. Such a sequence of displacements will yield a sequence of *states*, any two of which will have the ordering relation that one is *prior*, and the other is *subsequent*. To reflect the ordering in this sequence of fundamental states, we will usually refer to the states as *levels*.

We thus arrive at the following two postulates:

1. The basic element for creating the physical universe, and the basic information element, is a type of *displacement*. Specifically: *displacement from a prior level*.
2. The basic (information) structure is a *sequence* of such displacements.

With respect to the first postulate, we may refer to both displacements and levels as "elements" (or *basic* elements) of the system, but will reserve the term "basic *information* element" for the displacements alone.

We note that these displacements have a *direction* associated with them: they point from a prior level to a subsequent level (as will become more clear in section 2). This leads us to think of the displacements as *vectors*. Furthermore, just as with the states A and B, we assume that any two displacements or levels in the sequence have the relation that one is *ontologically* prior, and the other is ontologically subsequent; thus independence and dependence relations hold between them. These considerations suggest two more postulates:

3. Each displacement is a *one*-dimensional *vector*, constituting a *different*, but related, one-dimensional space. (The basic relations between these displacements/vectors are stated in the next postulate.)

4. Prior things (e.g. displacements, levels, and constructions from them) are *independent of* subsequent things; and, conversely, subsequent things are *dependent on* prior things. (As alluded to above, the terms "prior" and "subsequent" denote here *logical/ontological* relations, *not* temporal relations. Again, see [4].)

Some disambiguation is needed at this point. In mechanics, a "displacement" is a vector within *existing* 3-dimensional space, i.e. within ordinary space. In the present model, however, we *do not* take ordinary space as pre-existing; in fact, via the postulates above, we will *derive* ordinary space (section 3.1). We thus take the postulated displacements as one-dimensional entities in themselves, without thinking of them as occurring within an existing space.

It may be noted that the basic information element and basic information structure for the universe (as postulated above) are analogous to those of digital electronics, where either a finite or zero *displacement from a lower voltage level* constitutes a "1" or a "0", respectively, yielding a *bit*, and a sequence of eight such displacements constitutes a *byte*. And, just as the operations of a digital computer can thus be considered a *calculus of displacements from a lower voltage level*, so also the present model for constructing the physical universe can be considered a *calculus of displacements from prior levels*. In the case of digital computers, the calculus involves the operations of AND, OR and NOT logic gates on the voltage displacements, as well as the operations of control structures. In the present model, the calculus involves (the operations of) the dependence and independence *relations* between the displacements, as per postulate 4. Thus, if we allow that the postulated displacements represent a new kind of "bit", then the present model definitely qualifies as "It from bit" [1].

What is displaced? In section 4, it will be assumed that *energy* is displaced from one level to another. However, in the first three sections we will focus on the *logical* aspects of the displacements and their relations with one another, and the *geometrical* consequences.

Of course, a viable model for constructing the physical universe should offer answers to fundamental questions, such as: What is the origin of ordinary, three-dimensional space? What is dark energy? Why is the cosmological constant so small? Why does the presence of energy affect space and time? Why is the speed of light absolute, whereas other speeds are relative? Why are particle locations (in quantum mechanics) smeared across space by default? And, what factors are involved in "collapsing" the default smeared state into a definite position?

Indeed, using the four postulates above (and two more that will be stated later), we develop a model for the basic construction of the physical universe --- including the construction of ordinary space and time, a quantum of action, fundamental particles and interactions, inflation, dark energy, the cosmological constant, etc. As development of the model progresses, the essential role of "observers" in the construction process becomes more and more clear. With respect to question (iii) above, it will be shown that a method for translating a sequence of displacements into physical meaning is by taking into account *relations* between the displacements --- specifically, their dependence and independence relations (i.e. postulate 4). In particular, such relations will allow us to derive a (3+1)-dimensional structure which, in the context of the model, is best interpreted as the ordinary space and time dimensions of our experience.

From now on, I will often refer to the model developed herein as *system P*, and the world so constructed from it as *world P*. The choice of the letter "P" reflects the presumption that world P corresponds to the ***p***hysical universe.

2 Displacements, levels, and relations: the structure and basic properties of system P

To construct our model for the physical universe (i.e. system P), we must begin with a state at which the things of the universe do not exist (otherwise our construction would be circular), i.e. a state that is absent the elementary particles, and even space and time, as we know them. We will call this state *level 0*. We do not, however, presume that level 0 is a state of nothingness, or that nothing exists at level 0. We merely claim that nothing that comes into being with the construction of the universe exists at level 0; for level 0 is by definition a *state* that is immediately *prior* to the construction of the physical universe. (Level 0 thus corresponds to state A in the introduction.)

Recalling our first three postulates, we say that a displacement from level 0, to be denoted as $\mathbf{d}_0$, generates a *new* state, which we call *level 1*. Likewise, a displacement from level 1, denoted as $\mathbf{d}_1$, generates another new state, which we call *level 2*. And a displacement from level 2, denoted as $\mathbf{d}_2$, yields *level 3*; and so on. So, in general, $\mathbf{d}_k$ represents a displacement from level k that generates level $k + 1$ (for $k = 0, 1, 2, \ldots$); thus, relative to each other, level k is *prior*, and level $k + 1$ is *subsequent*; also, relative to each other, $\mathbf{d}_k$ is prior, and $\mathbf{d}_{k+1}$ is subsequent. (Again, the terms "prior" and "subsequent" refer to logical/ontological priority and subsequence.)

In Fig. 1, where levels are represented by horizontal lines, and displacements are represented by vertical arrows from a prior level to the next subsequent level, we illustrate the construction of levels 1 through 4 via displacements $\mathbf{d}_0$ through $\mathbf{d}_3$. To the right of each level in Fig. 1 is shown the sequence of displacements that is required to construct that level (the round brackets indicate a sequence, as is common in mathematics). Thus, the sequences of displacements that are needed to create levels 0, 1, 2, and 3 are ( ), ($\mathbf{d}_0$), ($\mathbf{d}_0$, $\mathbf{d}_1$), and ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$), respectively; and the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$) constructs all of the levels (above level 0) in Fig. 1.

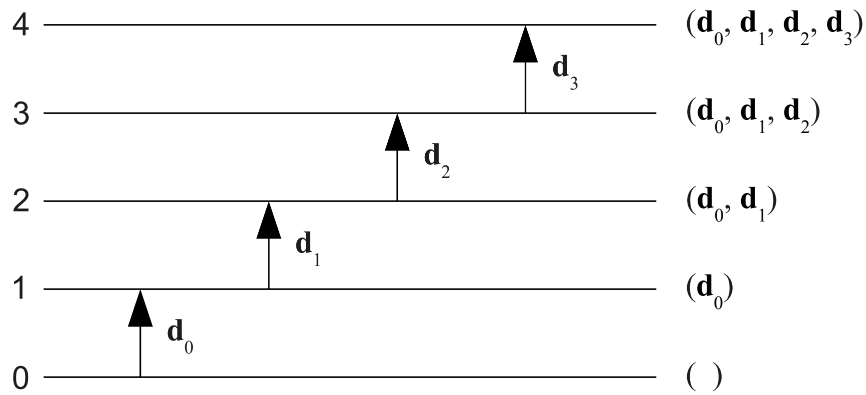

Fig. 1 Construction of levels 1 through 4 via the displacement sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$). The displacement sequence that is required to construct a given level is shown to the right of that level.

As just described, the *order* of construction starts with level 0 at the bottom of Fig. 1 and proceeds in the upward direction. Thus, level 0 is *prior* to all other elements (levels or displacements), and *subsequent* to none; $\mathbf{d}_0$ is subsequent to level 0, but prior to level 1, $\mathbf{d}_1$, level 2, etc.; and so on. So, in general, a given element *x* is subsequent to everything below it in Fig. 1, but prior to everything above it. By postulate 4, this means that element *x* is *dependent* on everything below it in the Figure, but *independent* of everything above it. Thus, for example, level 0 is independent of all other elements, and dependent on none.

Since level 0 is our *starting point* (or starting *state*) for constructing system P, then we must say that it is a *nonconstructed* element of that system, whereas the subsequent displacements and levels ($\mathbf{d}_0$, level 1, $\mathbf{d}_1$, level 2, etc.) are *constructed* elements of the system. So anything subsequent to level 0 is a *constructed* entity of the system.

2.1 Some properties of system P

Let *x* be a thing of system P (e.g. *x* is a level, a set of one or more displacements, or something constructed from them). By postulate 4, things that are subsequent to *x* are (logically/ontologically) *dependent* on *x*. Such dependence implies that *x* is **in effect**, effective, operative, or **operant** at those subsequent things; or, alternatively, we say that those subsequent/dependent things are *within the* **scope** *of x*. Conversely, since things that are *prior* to *x* are *independent* of it, we say that *x* is *not* in effect or operant at those prior things; or, alternatively, we say that those prior/independent things are *not* within the scope of *x*. All of this is summarized in what will be called the **scope rule**, stated as follows:

> A given thing in system P is in effect/operant at (i.e. contains within its scope) those things which are *subsequent*, and is not in effect at (does not contain within its scope) those things which are *prior*.

From this we may deduce the following corollary to the scope rule:

> A given *element* in system P (i.e. a displacement or level) is in effect/operant at (contains within its scope) those elements that are *above* it in Fig. 1, and is not operant at (does not contain within its scope) those elements that are *below* it in Fig. 1.

Thus, for example, since all of the *constructed* elements of system P (i.e. $\mathbf{d}_0$, level 1, $\mathbf{d}_1$, level 2, etc.) are subsequent to level 0 (or, conversely, level 0 is prior to them), then level 0 is in effect/operant at all of those things; or, all of those things are within the scope of level 0. Likewise, $\mathbf{d}_1$, level 2, $\mathbf{d}_2$, level 3, etc., are within the scope of level 1; but level 0 is *not* within the scope of level 1. And so on.

Since $\mathbf{d}_k$ is *not* in effect at level k, but *is* in effect at level $k+1$, then level $k+1$ represents the *state* at which the displacement $\mathbf{d}_k$ first comes into effect; by the scope rule, $\mathbf{d}_k$ then *stays* in effect for all subsequent levels. Thus, the displacement $\mathbf{d}_0$ first comes into effect at level 1, and stays in effect for levels 2, 3, and 4; likewise, $\mathbf{d}_1$ first comes into effect at level 2, and stays in effect for levels 3 and 4. Let us say that the level at which a displacement first comes into effect is its *native level*. Thus, level 1 is the native level for $\mathbf{d}_0$; level 2 is the native level for $\mathbf{d}_1$; and so on. That is, the native level for $\mathbf{d}_k$ is level $k+1$. Moreover, the concept of native level can be extended to things that are *constructed from* displacements; thus, for example, something that is constructed using $\mathbf{d}_0$ and $\mathbf{d}_1$ (and no other displacements) is native to level 2, since those two displacements are first *jointly* in effect at that level. We note also that the displacements that are in effect/operant at a given level are the *same* as the ones that are required to *construct* that level (as described earlier, and as listed in the sequences to the right of each level in Fig. 1).

As described above, the scope of a given element *contains* the scope of the next subsequent element, and is contained (or nested) *within* the scope of its immediately prior element (if any). Thus, the scopes of the sequence of elements in system P can be pictured as a (Russian-doll-like) structure of concentric spheres; the outer sphere being the scope of level 0, the first inner sphere being the scope of $\mathbf{d}_0$, the next inner sphere being the scope of level 1, and so on. Again, since this applies to *elements* of system P, it also applies to things that are associated with or constructed from them. This leads to the following general statement, which will be referred to as the **nesting rule** for system P:

> Subsequent things (e.g. levels, displacements, and any constructions derived from them) are *internal to* or *nested* (and thus embedded, contained, encapsulated, confined) *within* the scope of prior things; and, conversely, prior things contain, encapsulate and confine (within their scope) subsequent things.

Thus the nesting rule may also be called the *confinement* rule.

In constructing the sequence of displacements ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$), since any displacements that are in effect at level k are also in effect at the subsequent level $k+1$, then we can think of the latter level as *inheriting* all of the displacements that are in effect at the former level. And since this is true of displacements, then it is also true of anything that is associated with or constructed from them. This aspect of system P --- whereby, in constructing the said sequence, things that are created at one level (or, if you will, *generation*) are passed on to the next subsequent level (and thus, by extension, to *all* subsequent levels) --- will be called the **inheritance rule**.

Since the sequence of displacements, ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$), that constructs system P springs out of level 0 of that system, then we can say that level 0 is the *origin* of system P. And since, by the nesting/confinement rule, all of the constructed elements/entities of that system are logically nested/confined within level 0, then we can also say that level 0 is the *boundary* of system P. Thus, level 0 is both the origin *and* boundary of system P; so, in that sense, although level 0 is a necessary part of the ontology of system P, it is not technically *within* system/world P. Furthermore, since system P is a model for constructing the physical universe, then we have shown that, according to this model: (a) The *origin and boundary* of the physical universe are the *same* thing (which we call level 0); (b) the origin/boundary of the universe is a fundamental, logical *state*, not a spatiotemporal *place*. This result is therefore the first step in liberating our minds from the problematic influence of spatiotemporal thinking regarding the fundamental construction process for the universe (e.g., treating big-bang-style spatiotemporal evolution, with accompanying "singularity", as fundamental); and it is the first step toward shifting our minds onto a purely-logical model of this process. As we will see, logic dictates geometry, not the other way around.

Finally, when a set of things in system P (i.e. elements, or things constructed from them) is arranged from prior to subsequent, then we will say that the things are arranged in their *order of priority*. If a thing is neither prior nor subsequent to another thing, then we say that they are *of the same order*, or *coordinate*.

3 Constructing spaces

Following postulate 3, let us model each displacement as a one-dimensional *vector*; i.e. we model each $\mathbf{d}_k$ ($k = 0, 1, 2, \ldots$) as a one-dimensional vector going from level k to level $k+1$. Thus, $\mathbf{d}_0$ is a one-dimensional vector from level 0 to level 1; $\mathbf{d}_1$ is a one-dimensional vector from level 1 to level 2; and so on. These vectors are represented graphically by the vertical arrows in Fig. 1.

Moreover, each $\mathbf{d}_k$ constitutes a *different* one-dimensional space. Though they are different in this respect, the $\mathbf{d}_k$ are nevertheless *related* by the dependence and independence relations that have been postulated and discussed.

3.1 Constructing a (3+1)-dimensional structure at level 2

Since $\mathbf{d}_0$ is the only displacement in effect at level 1, and since (by postulate 3) it is *one* dimensional, then it is fair to say that system P is *one dimensional* at level 1.

Since both $\mathbf{d}_0$ and $\mathbf{d}_1$ are in effect at level 2, and since (by postulate 3) each of these constitutes a different one-dimensional space, then it might seem --- at first glance --- that system P should be *two* dimensional at level 2. But this would be wrong.

To get the correct dimensionality at level 2, we must take into account the *relations* between $\mathbf{d}_0$ and $\mathbf{d}_1$, as per postulate 4 --- i.e. the fact that $\mathbf{d}_0$ is *independent* of $\mathbf{d}_1$, and that this relation is *asymmetric* ($\mathbf{d}_1$ is *dependent* on $\mathbf{d}_0$). Since $\mathbf{d}_0$ and $\mathbf{d}_1$ are *vectors*, we interpret that these relations imply a kind of (asymmetric) *linear* independence, with the following property: from the perspective of $\mathbf{d}_1$, the vector $\mathbf{d}_0$ may be collinear with $\mathbf{d}_1$, but is also free to be *noncollinear* with $\mathbf{d}_1$. With these considerations in mind, we ask the question: What is the *direction* of $\mathbf{d}_0$ with respect to $\mathbf{d}_1$? Or, in other words, how does $\mathbf{d}_0$ "look" relative to $\mathbf{d}_1$?

Since $\mathbf{d}_0$ may be both collinear and noncollinear with $\mathbf{d}_1$ (from the latter's perspective), then $\mathbf{d}_0$ may have a component parallel to $\mathbf{d}_1$, and may also have a component *perpendicular/orthogonal* (i.e. at 90 degrees) to $\mathbf{d}_1$. But, by symmetry, the perpendicular component can be anywhere in a two-dimensional *plane* orthogonal to $\mathbf{d}_1$. The two dimensions of this orthogonal plane, plus the one dimension parallel to $\mathbf{d}_1$, makes three dimensions. Thus, from the viewpoint of $\mathbf{d}_1$ (and from the perspective of level 2), $\mathbf{d}_0$ has *three* dimensions; i.e. $\mathbf{d}_0$ constitutes a *three*-dimensional space (whereas, recall that $\mathbf{d}_0$ has only one dimension at level 1). We might say, therefore, that the view of $\mathbf{d}_0$ from the perspective of $\mathbf{d}_1$ "bootstraps" the former from a one-dimensional vector into a three-dimensional space.

In summary, to construct its interpretation of $\mathbf{d}_0$, we can think of $\mathbf{d}_1$ as applying postulates 3 and 4 in succession: first, by postulate 3, $\mathbf{d}_0$ is a one-dimensional vector; second, by postulate 4, $\mathbf{d}_0$ is independent of $\mathbf{d}_1$ --- which allows the former to have a component that is orthogonal to $\mathbf{d}_1$, with the result that $\mathbf{d}_1$ sees $\mathbf{d}_0$ as three dimensional.

Conversely, we can ask, how does $\mathbf{d}_1$ "look" relative to $\mathbf{d}_0$? Since $\mathbf{d}_1$ is *dependent* on $\mathbf{d}_0$, then the former is *not* free to have a component that is orthogonal to the latter, and so $\mathbf{d}_0$ sees $\mathbf{d}_1$ as being collinear; or, more simply, $\mathbf{d}_0$ sees $\mathbf{d}_1$ strictly as per postulate 3: as a *one*-dimensional vector. (By the scope rule, this view of $\mathbf{d}_1$ --- from the perspective of $\mathbf{d}_0$ --- is then also available at *level 2 and above*, and actually can only produce an effect at those levels, since $\mathbf{d}_1$ itself is only *operant* at those levels.)

So, at level 2 we have the three dimensions of $\mathbf{d}_0$, plus the one dimension of $\mathbf{d}_1$, for a total of *four* dimensions. Since system P is a model for constructing the physical universe, we interpret that the three dimensions of $\mathbf{d}_0$ are just the three dimensions of *ordinary space*, and the one dimension of $\mathbf{d}_1$ is the dimension of *time*; thereby yielding at level 2 the signature 3+1 space and time dimensions of our experience. The dimension of time, therefore, being a consequence of $\mathbf{d}_1$ (and $\mathbf{d}_0$), does not exist at levels 0 and 1, but only comes into existence at level 2; likewise, since ordinary, three-dimensional space is a consequence of $\mathbf{d}_0$ and $\mathbf{d}_1$, it also does not exist at levels 0 and 1, but only comes into existence at level 2.

Note that, although $\mathbf{d}_0$ itself is independent of $\mathbf{d}_1$, the triple dimensionality of $\mathbf{d}_0$ at level 2 is *not* independent of $\mathbf{d}_1$. That is, in the process described above, $\mathbf{d}_0$ only manifests as *three* dimensional when it is related to, or juxtaposed with, $\mathbf{d}_1$. Thus, the triple dimensionality of $\mathbf{d}_0$ at level 2 (i.e. the triple dimensionality of ordinary space) is in fact *dependent* on $\mathbf{d}_1$. Conversely, both $\mathbf{d}_0$ and $\mathbf{d}_1$ are *prior* to, and thus independent of, ordinary space.

We have shown, among other things, that $\mathbf{d}_0$ manifests differently at levels 1 and 2. At level 1 it is *one* dimensional. But when juxtaposed with $\mathbf{d}_1$ at level 2 it manifests as a *three*-dimensional space. Note that $\mathbf{d}_0$ itself does not change from level to level: it represents a displacement from level 0 to level 1 wherever it appears (i.e. wherever it is in effect). This is analogous to, e.g., the G nucleotide in biology, which is always the same molecule wherever it appears, but yields a different output (i.e. amino acid) depending on what other nucleotides/letters it is juxtaposed with in a sequence. In other words, like the letter G in a DNA sequence, the *meaning* of $\mathbf{d}_0$ is context dependent; which is just what we might expect for an element of a *language*, thus supporting our earlier notion that the basis of the physical universe is, to some degree at least, informational in nature.

We might say that level 2 has *two* dimensions as *input* (one for $\mathbf{d}_0$, plus one for $\mathbf{d}_1$), but has *four* dimensions as *output* --- three for $\mathbf{d}_0$, and one for $\mathbf{d}_1$. Which brings us back to question (iii) in the introduction: How are the basic information elements of the model (which at level 2 are the inputs $\mathbf{d}_0$ and $\mathbf{d}_1$) translated (or, if you will, *computed*) into the meaningful output that we call the physical universe? We now see that at least a partial answer is that the *relations* between prior and subsequent elements are what translate them into meaningful output. In the present case, the independence relation between $\mathbf{d}_0$ and $\mathbf{d}_1$ at level 2 translates/transforms the manifestation of the former from a one-dimensional entity into a three-dimensional space.

We can thus say that the construction of each space at level 2 requires the participation of an *observer*, in the sense that $\mathbf{d}_1$ "observing" $\mathbf{d}_0$ constructs ordinary, three-dimensional space, and $\mathbf{d}_0$ "observing" $\mathbf{d}_1$ constructs one-dimensional time. With ordinary space *itself* constructed by an observation of sorts, it becomes more plausible that, e.g., the *position* of an object *within* ordinary space might also be constructed by some type of observation, as seems to be the case in quantum mechanics (more about that in section 4.13).

We have just described how the spaces and dimensionalities at level 2 are constructed. Now we will do the same for levels 3 and 4.

3.2 The spaces of levels 3 and 4

At level 3, the displacements $\mathbf{d}_0$, $\mathbf{d}_1$, and $\mathbf{d}_2$ are in effect.

The relations between $\mathbf{d}_0$ and $\mathbf{d}_1$ at level 3 are the same as they are at level 2 (i.e. $\mathbf{d}_0$ is independent of $\mathbf{d}_1$, but not the converse). Thus, at level 3 --- as at level 2 --- $\mathbf{d}_0$ will appear to $\mathbf{d}_1$ as a three-dimensional space (i.e. ordinary space), and $\mathbf{d}_1$ will appear to $\mathbf{d}_0$ as a one-dimensional space (i.e. time). In other words, the spaces that exist at level 2 also exist at level 3. Indeed, as per the inheritance rule, we might say that level 3 *inherits* these spaces from level 2; or, more precisely, level 3 inherits $\mathbf{d}_0$, $\mathbf{d}_1$, and the relations between them from level 2, and uses them to *construct* ordinary space and time.

Let us denote ordinary, three-dimensional space as S^3_{01}, where the superscript indicates the number of dimensions, and the 0 followed by 1 in the subscript indicates that this is the space of $\mathbf{d}_0$ as seen by $\mathbf{d}_1$. Likewise, let us denote time as S^1_{10}, where, again, the superscript indicates the dimension of this space, and the 1 followed by 0 in the subscript indicates that this is the space of $\mathbf{d}_1$ as seen by $\mathbf{d}_0$.

Focusing again on level 3, we start by discussing the relations between $\mathbf{d}_0$ and $\mathbf{d}_2$ at that level. The former is independent of the latter, so $\mathbf{d}_0$ is *three* dimensional from the viewpoint of $\mathbf{d}_2$. We thus have the generation of a *new* three-dimensional space at level 3, which we denote as S^3_{02}. Likewise, $\mathbf{d}_1$ is independent of $\mathbf{d}_2$; so the latter will see $\mathbf{d}_1$ as three dimensional (whereas, as already stated, $\mathbf{d}_1$ has only one dimension from the viewpoint of $\mathbf{d}_0$). This yields yet another three-dimensional space at level 3, which we denote as S^3_{12}. In addition, at level 3 we also have the *one*-dimensional space, S^1_{20}, of $\mathbf{d}_2$ as seen by $\mathbf{d}_0$; and the one-dimensional space, S^1_{21}, of $\mathbf{d}_2$ as seen by $\mathbf{d}_1$. We note that all of these new spaces depend on $\mathbf{d}_2$, so they are only operant at level 3 and above; furthermore, they are subsequent to ordinary space, S^3_{01}, and so they are *nested* within it.

We now ask, *where* are the *three*-dimensional spaces located relative to each other? The three-dimensional spaces at level 3 have the order of priority S^3_{01}, S^3_{02}, S^3_{12}; [1] so, by the nesting rule, S^3_{12} is nested/contained/confined within S^3_{02}, which in turn is nested/confined within S^3_{01} (ordinary space); or, to put it another way, S^3_{01} (ordinary space) contains S^3_{02}, which in turn contains S^3_{12}.

Now let us move up to level 4, where the displacements $\mathbf{d}_0$, $\mathbf{d}_1$, and $\mathbf{d}_2$ are still in effect. So the spaces of level 3 also exist at level 4. In addition, the displacement $\mathbf{d}_3$ is in effect at level 4, so the relationship between it and the prior displacements $\mathbf{d}_x$ ($x = 0, 1, 2$) generates three new, three-dimensional spaces, which we denote collectively as S^3_{x3}; and we note that these spaces will be internal to, or nested within, S^3_{12}. Lastly, there are the three new, one-dimensional spaces of: $\mathbf{d}_3$ as seen by $\mathbf{d}_0$, denoted as S^1_{30}; $\mathbf{d}_3$ as seen by $\mathbf{d}_1$, denoted as S^1_{31}; and $\mathbf{d}_3$ as seen by $\mathbf{d}_2$, denoted as S^1_{32} --- which may be denoted collectively as S^1_{3y} ($y = 0, 1, 2$).[2] These new spaces at level 4 are also nested within ordinary space, S^3_{01}.

3.3 The number of dimensions at levels 2, 3, and 4

At level 2 the *four* dimensions of S^3_{01} and S^1_{10} are in effect. At level 3, the same four dimensions at level 2 are in effect, plus the eight additional dimensions of S^3_{02}, S^3_{12}, S^1_{20}, and S^1_{21}, which makes a total of *twelve* dimensions at level 3. And at level 4, the same twelve dimensions at level 3 are in effect, plus the 12 additional dimensions of S^3_{x3} ($x = 0, 1, 2$) and S^1_{3y} ($y = 0, 1, 2$), for a total of 24 dimensions at level 4.

1 Obviously, S^3_{01} is prior to the other two, since it is native to level 2, whereas the others are native to level 3. S^3_{02} is prior to S^3_{12} since the former is a manifestation, or mode, of $\mathbf{d}_0$, whereas the latter is a mode of $\mathbf{d}_1$ (and the former displacement is prior to the latter).

2 Note that, for a space S^z_{xy}, the superscript, z, is actually *redundant* information, since it is always equal to 3 if $x < y$, and is equal to 1 if $x > y$.

The *union* of spaces at levels 2 and 3 is the *twelve*-dimensional set

$$\{ S^1_{10},\ S^3_{01},\ S^3_{02},\ S^3_{12},\ S^1_{20},\ S^1_{21} \},$$

and the union of spaces at levels 2, 3, and 4 is the *twenty-four*-dimensional set

$$\{ S^1_{10},\ S^3_{01},\ S^3_{02},\ S^3_{12},\ S^1_{20},\ S^1_{21},\ S^3_{x3}\ S^1_{3y} \}.$$

And we note that the 10 "extra" spaces (or 20 extra dimensions) of these sets (i.e. the spaces/dimensions that are native to levels 3 and 4) are *nested/confined* --- and, indeed, as will be concluded in section 4.4.4, *compacted* --- within ordinary space, S^3_{01}. The dimensionalities of system P thus bear some similarity to dimensionalities in string theory [5], [6]. Does this suggest that the displacements of the present model have some relation to *strings*? Possibly --- but we will not specifically expand on the string idea any further in this paper.

As alluded to, more will be said about the nested spaces of levels 3 and 4 in section 4, where we construct the *particles* of system P.

3.4 Isotropy and homogeneity of ordinary space

Recall that ordinary, three-dimensional space is created when $\mathbf{d}_0$ is viewed from the perspective of $\mathbf{d}_1$. So it follows that (a) the creation/construction of ordinary space is *dependent* on $\mathbf{d}_0$ and $\mathbf{d}_1$; and (b) $\mathbf{d}_0$ and $\mathbf{d}_1$ are *prior to*, and thus (by postulate 4) *independent of*, ordinary space.

Suppose now that an outcome of constructing ordinary space is that $\mathbf{d}_0$ (or $\mathbf{d}_1$) manifests with a particular orientation or direction within that space. Since this would make $\mathbf{d}_0$ (or $\mathbf{d}_1$) functionally dependent on ordinary space, and thus contradict (b) above, we conclude that the construction of ordinary space cannot result in $\mathbf{d}_0$ (or $\mathbf{d}_1$) having a particular direction/orientation within that space. Presumably, then, there is no way that the process of constructing ordinary space can establish a distinctive (i.e. special, preferred, or favored) direction within that space. We thus conclude that, as constructed above, ordinary space is perfectly *isotropic*.

Now suppose that an outcome of constructing ordinary space is that $\mathbf{d}_0$ (or $\mathbf{d}_1$) manifests with a particular *position* within that space. This, again, would make $\mathbf{d}_0$ (or $\mathbf{d}_1$) functionally dependent on ordinary space, and thereby contradict (b) above; and so we conclude that the construction of ordinary space cannot result in $\mathbf{d}_0$ (or $\mathbf{d}_1$) having a particular position within that space. Presumably, then, the process that constructs ordinary space cannot establish a distinctive (i.e. special, preferred, or favored) position within that space. We thus conclude that, as constructed above, ordinary space is perfectly *homogeneous*.

In addition, the construction of ordinary space cannot result in either $\mathbf{d}_0$ or $\mathbf{d}_1$ manifesting as *vectors*, or *vector fields*, within that space; for if they did, then these displacements/vectors would be functionally dependent on ordinary space, which would again contradict (b). Given that *vector* fields have been ruled out, it seems we have little choice but to assume that $\mathbf{d}_0$ and $\mathbf{d}_1$ manifest within ordinary space as uniform *scalar* fields --- *uniform*, because any *non*uniformity would make the manifestations of $\mathbf{d}_0$ or $\mathbf{d}_1$ functionally dependent on ordinary space, which would, again, violate/contradict their independence from that space. Presumably, the uniform scalar field for $\mathbf{d}_0$ is just ordinary space itself, and/or the energy associated with it (to be elaborated in sections 4.4.1 and 4.4.3). On the other hand, the uniform scalar field associated with $\mathbf{d}_1$ might be a kind of null field, i.e. not significantly manifesting in the construction of ordinary space, since $\mathbf{d}_1$ is the *observing* element in this process (whereas $\mathbf{d}_0$ is the *observed* element); that is, in a process involving observing and observed elements, it may be that we only need to concern ourselves with how the *observed* element manifests.

We have seen above that the process of constructing ordinary space "washes out" the directionality (i.e. vectorial nature) of both $\mathbf{d}_0$ and $\mathbf{d}_1$, leaving them to manifest (at most) as scalar fields. However, in the next section it is argued that a different process (namely, the view of $\mathbf{d}_1$ from the perspective of $\mathbf{d}_0$, which yields time) *preserves* $\mathbf{d}_1$'s directionality, yielding the arrow of time. Furthermore, it is argued much later (in section 4.13) that additional processes (namely, the views of $\mathbf{d}_0$ and $\mathbf{d}_1$ from the perspective of *level 0*) also preserve directionality in those displacements (yielding relative position and relative velocity vectors, respectively).

3.5 Ordinary/classical time

Since $\mathbf{d}_0$ is prior to $\mathbf{d}_1$, then we will assume that $\mathbf{d}_0$'s view of $\mathbf{d}_1$ (which constructs 1-dimensional *time*) is prior to $\mathbf{d}_1$'s view of $\mathbf{d}_0$ (which constructs ordinary, 3-dimensional space). It then follows that the time dimension (as constructed) is prior to, and thus independent of, ordinary space. Given its independence, it also follows (by the same reasoning used in section 3.4) that the time dimension must manifest *uniformly* throughout ordinary space; i.e., it must operate the *same* everywhere in space. (For, if it *did not* operate the same everywhere, it would be functionally dependent on ordinary space, thereby yielding a contradiction.)

Moreover, recall that $\mathbf{d}_0$ sees $\mathbf{d}_1$ as a one-dimensional *vector*, thereby preserving the *directionality* of $\mathbf{d}_1$ in this process. We interpret that this directional aspect of $\mathbf{d}_1$ (with respect to $\mathbf{d}_0$) is just the "arrow" of time. However, if this arrow/directionality of time were to manifest as a particular direction in ordinary space, it would again violate the time dimension's independence from that space; thus, the directional aspect of $\mathbf{d}_1$ (with respect to $\mathbf{d}_0$), i.e. the arrow of time, is not married to any particular direction in ordinary space (as comports with observation/experience).

In summary, we interpret that $\mathbf{d}_0$'s view of $\mathbf{d}_1$ produces what might be called *ordinary time*, or *classical time* --- i.e., time as the independent variable in classical mechanics (which indeed manifests and operates the same everywhere in space).

The *modification* of time (intervals) that occurs in special relativity is due to the absoluteness of the speed of light, which we derive in section 4.13.3. The modification of time due to gravity is accounted for in section 4.14.

Finally, since the process that constructs time is necessarily *prior to* time itself, then that process is *independent of time*; thus, there is no way *in* time for it to "timeout" or "turn off". Consequently, the construction of time is a *continual*, ongoing process; and so time manifests as a *stream*.

3.6 Rapid expansion of ordinary space within the first instant of time

Recall that $\mathbf{d}_0$ at level 1 is *one* dimensional --- having, let us say, a length of d_0. The time dimension, being a result of $\mathbf{d}_1$, does not exist at this level/stage. Given that a one-dimensional object has *zero* volume, then the physical universe at this stage of development has a volume of zero.

Since the time dimension comes into existence with the displacement $\mathbf{d}_1$, then the *advent* of $\mathbf{d}_1$ defines the time $t = 0$, at which point d_0 has the value $d_0(t = 0)$, which may be denoted as $d_{0,0}$. So, at exactly $t = 0$, or within the first instant after it, the existence/perspective of $\mathbf{d}_1$ causes $\mathbf{d}_0$ to manifest as the *three*-dimensional space S^3_{01}, with a volume that should be proportional to $d^3_{0,0}$. Thus the volume of S^3_{01} (ordinary space) goes from zero to around $d^3_{0,0}$ within a time interval of zero, or near-zero, length --- which constitutes a potentially very large, perhaps infinite, rate of spatial expansion. I propose, therefore, that this rapid spatial expansion, triggered by the advent of $\mathbf{d}_1$ at $t = 0$, is the process known as *inflation* [7].

Note that, under the above mechanism, inflation has a natural beginning: the advent of $\mathbf{d}_1$ at $t = 0$. And it also has a natural *ending*: it ends when the volume of ordinary space is around $d^3_{0,0}$. So inflation only lasts for the time (if any) that it takes (from the perspective of $\mathbf{d}_1$) for the *one*-dimensional space of length $d_{0,0}$ to become the *three*-dimensional space of approximate volume $d^3_{0,0}$.

4 Constructing particles

4.1 Basic energy considerations

In constructing the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$), let us assume that *energy* is needed to create each of the displacements $\mathbf{d}_k$ ($k = 0, 1, 2, 3$). We can think of this energy as being stored along the length of $\mathbf{d}_k$, and/or as being stored in the *level* ($k + 1$) that is created by $\mathbf{d}_k$. So we can speak of "$\mathbf{d}_k$ energy", which emphasizes the displacement that the energy is associated with, or we can speak of "$E_{[k+1]}$ energy", which emphasizes the level ($k + 1$) into which the energy is placed.

The displacement $\mathbf{d}_0$, then, is a *process* through which $\mathbf{d}_0$ energy is input into level 1, thereby also making it E_1 energy. Likewise, $\mathbf{d}_1$ is a process that inputs $\mathbf{d}_1$ energy into level 2, thereby making it E_2 energy; $\mathbf{d}_2$ is a process that places $\mathbf{d}_2$ energy into level 3, thereby making it E_3 energy; and so on. We assume that all of these energies are nonzero and positive. So the energy of the system, due to contributions from the sources mentioned, is positive.

4.2 Aspects of energy flow and identity

In terms of energy *flow*, the construction of the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$) proceeds as follows:

- First, the displacement $\mathbf{d}_0$ inputs "$\mathbf{d}_0$ energy" into level 1, thereby making it also "E_1 energy".
- Next, some of the E_1 energy at level 1 is then input into level 2 via the displacement $\mathbf{d}_1$, thereby making it "E_2 energy" --- but, due to its provenance (and the inheritance rule), still also retaining its essential identity as E_1 energy.
- Some of the E_2 energy at level 2 is then input into level 3 via the displacement $\mathbf{d}_2$, thereby making it "E_3 energy" --- while also retaining its prior identities as E_1 energy and E_2 energy.
- And so on for the $\mathbf{d}_3$ process, with corresponding "E_4 energy"; etc.

It follows that, in constructing the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$), E_j energy is also E_{j-1} energy, E_{j-2} energy, ..., E_1 energy. Thus, *all* of these E_j energies are essentially also "E_1 energy". Moreover, *all* of the needed energy for constructing this sequence *enters* the system via the displacement $\mathbf{d}_0$, and thus begins its life in the system as E_1 energy at level 1. Its essential identity as "E_1 energy" is retained, even as it is displaced up to subsequent levels and becomes also E_2 energy, E_3 energy, etc.

In summary, the term "$\mathbf{d}_k$ energy" (k = 0, 1, 2, 3) informs us about the *process* by which energy is placed into level $k + 1$ when constructing the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$). The designation "$E_{[k+1]}$ energy", on the other hand, is a kind of "brand" that energy receives when it enters level $k + 1$, which then survives subsequent displacement to higher levels (if any). Thus, the set of E_j energies possessed by a given quantity of energy keeps track of the *provenance* of that energy in entering the system, and the subsequent *path* (if any) that it takes within the system. So, for example, if a given quantity of energy is said to have the energies E_1, E_2, and E_3, then we know that it entered the system at level 1, and was subsequently displaced up to level 3.

It should be clear at this point that the labels E_1, E_2, E_3, etc., *do not* denote *quantities* of energy; rather, they denote *types* (or forms, or flavors) of energy. Everyone is familiar with the standard types of energy in physics: kinetic, potential, and rest energies. In the present model, however, the E_j energies (j = 1, 2, 3, 4) are considered to be more fundamental.

The displacement $\mathbf{d}_0$ (or the $\mathbf{d}_0$ process) is therefore the portal or "pipe" through which E_1 energy comes into the system, suggesting the following criteria for that energy type:

> A given *quantity* of energy is "E_1 energy" if and only if (a) it *enters* the system at level 1; and (b) its *entry* into the system is thereby dependent on the displacement $\mathbf{d}_0$, but is *independent* of the displacements $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$, etc.

Note that, as already alluded to, the *subsequent* energies that arise in constructing the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$) --- i.e. E_2 energy, E_3 energy, etc. --- also satisfy these criteria of E_1 energy. That is, *in constructing the said sequence*, the quantities of energy associated with

E_2, E_3, etc., share the *provenance* of entering the system via the $\mathbf{d}_0$ portal, whose entry is thus dependent on $\mathbf{d}_0$, but independent of $\mathbf{d}_1$, $\mathbf{d}_2$, etc. --- and so, by the above criteria, are "E_1 energy". Figuratively, we might say that, due to their common provenance in the displacement $\mathbf{d}_0$, those subsequent energies *inherit* the identity, nature, likeness, or "mantle" of E_1 energy (a result which might thus be attributed to the inheritance rule).

In terms of the scope rule, E_j energy becomes operant at level j, and stays in effect for all subsequent levels, $j + 1$, $j + 2$, etc; so E_j energy is *native* to level j. Thus, E_1 energy is native to level 1 (i.e. it is operant at level 1 and above); E_2 energy is native to level 2 (operant at level 2 and above); and so on.

4.3 A quantum of action

Recall that the dimension of time is associated with $\mathbf{d}_1$. Since $\mathbf{d}_1$ does not exist at levels 0 and 1, then time also does not exist there; thus, all time intervals are zero at those levels. Indeed, we can say that levels 0 and 1 are *independent of time*. But $\mathbf{d}_1$ *does* exist at level 2 and above; so time exists there, and presumably all significant (i.e. nontrivial) time intervals at those levels are nonzero (and positive).

Thus, at level 1, energy is nonzero, but time is zero. At level 2 (and above), however, both energy and time (intervals) are *nonzero*. Consequently, at level 2 and above, the *product* of energy and time --- the quantity known as *action* --- is nonzero, and thus has a positive lower bound; i.e., at level 2 (and above) the action is *quantized*. We thus have the derivation of an action *quantum*, which we interpret to be the basis for the empirically-known "quantum of action", commonly referred to as *Planck's constant*, and denoted as h.

In the present model, therefore, the quantum of action, h, depends on both $\mathbf{d}_0$ and $\mathbf{d}_1$, and so does not exist at levels 0 and 1, but only comes into being at level 2. Thus, quantum mechanics, which is based on h, also comes into being at level 2. And therefore, due to the scope rule, both h and quantum mechanics are operant at level 2 and above; i.e. they are *native* to level 2. Note that the advent of h at a relatively late stage (level 2) in the construction of system/world P is in contrast to the usual notion in which the quantum of action is assumed to (magically) operate at *all* phases in the construction of the physical universe.

The late advent of h in system P has the following immediate consequences:

- Because h is not operant at levels 0 and 1, then system P is not quantum mechanical at those primal levels, and so the system is not fundamentally quantum mechanical. Since system P is our model for constructing the physical universe, we conclude that the physical universe is not fundamentally quantum mechanical, and thus cannot have originated from a quantum effect (e.g. a "primordial quantum fluctuation") --- because the *source/origin* of the system is at level 0, and h does not exist there.
- The energy of quantum vacuum fluctuations (or zero-point energy) necessarily depends on h, which (as we have found) depends on both $\mathbf{d}_0$ and $\mathbf{d}_1$, and is native

to level 2. Therefore, quantum vacuum energy *enters* the system at *level 2 or above*, and its entry into the system is dependent on $\mathbf{d}_0$ *and* $\mathbf{d}_1$. Now recall our recent criteria for "E_1 energy": It enters the system at level 1; and its entry into the system depends only on $\mathbf{d}_0$, thereby making that entry independent of $\mathbf{d}_1$. Clearly, then, the energy of quantum fluctuations is *not* E_1 energy; rather, due to their dependence on $\mathbf{d}_1$, such fluctuations can presumably only produce E_j energy forms that are native to *level 2 or above* --- i.e. E_2 energy, E_3 energy, E_4 energy, and so on. This result will later be shown to have important implications for the cosmological constant problem (section 4.8.4).

4.4 Energy distribution in time and space

In constructing the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$), we know how the $\mathbf{d}_k$ energies are distributed among the *levels* (i.e. $\mathbf{d}_k$ energy is input into level $k + 1$), but how are they distributed in time and space? The following five factors of the model likely dominate the temporal and spatial distribution of these energies:

1. The displacement $\mathbf{d}_0$ is independent of ordinary space. (Section 3.4)
2. The displacements $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$, etc., are *subsequent* to $\mathbf{d}_0$.
3. At levels 0 and 1, neither time nor *h* exist.
4. At level 2 (and above), both time and *h* exist, and are thus in effect/operant.
5. At level 3, the space S^3_{12} is nested/confined within S^3_{02}, which in turn is nested/confined within S^3_{01} (ordinary space) (section 3.2).

The role of these factors in shaping energy distribution in time and space is elaborated in the next few subsections.

4.4.1 Large-scale distribution of energy within ordinary space

Recall that ordinary space is constructed when the displacement $\mathbf{d}_0$ is viewed from the perspective of $\mathbf{d}_1$ --- and that $\mathbf{d}_0$ is prior to, and thus *independent* of, that space (factor 1). Note also that, given $\mathbf{d}_0$'s priority to ordinary space, then (by the scope rule) $\mathbf{d}_0$ *is* operant (i.e. *does* manifest) throughout that space.

Now suppose that $\mathbf{d}_0$ (or some aspect of it) manifests *nonuniformly* within the ordinary space so constructed. Then $\mathbf{d}_0$ would be manifesting/operating as a variable function of position or direction within that space, and thus be functionally *dependent* on ordinary space --- thereby contradicting factor 1. This leads to the following conclusion: The view of $\mathbf{d}_0$ from the perspective of $\mathbf{d}_1$ not only constructs ordinary space, but also has the result that $\mathbf{d}_0$ (or any aspect of it) manifests *uniformly* throughout that space.

The above result leads immediately to a further conclusion: $\mathbf{d}_0$ energy, which the $\mathbf{d}_0$ process inputs into level 1, must be distributed *uniformly* throughout the volume of ordinary space. Moreover, given our earlier conclusion that the construction of ordinary space cannot result in $\mathbf{d}_0$ manifesting as a vector field within that space, then its $\mathbf{d}_0$ energy also cannot manifest as a vector field in ordinary space. Consequently, it seems that $\mathbf{d}_0$ energy must manifest within ordinary space as a uniform *scalar* field.

Since $\mathbf{d}_1$, $\mathbf{d}_2$, and $\mathbf{d}_3$ are *subsequent* to $\mathbf{d}_0$ (factor 2), then the nesting rule indicates that their associated energies --- $\mathbf{d}_1$ energy, $\mathbf{d}_2$ energy, etc. --- should be contained *within* $\mathbf{d}_0$'s distribution, i.e. contained within ordinary space. The (stronger) inheritance rule, however, indicates that those subsequent energies should inherit the *same* distribution as $\mathbf{d}_0$ energy. We therefore conclude that the subsequent $\mathbf{d}_k$ energies ($k = 1, 2, 3$) "follow the lead" of $\mathbf{d}_0$, and are thus also distributed uniformly throughout ordinary space. Hence, in terms of energy distribution within ordinary space: as $\mathbf{d}_0$ goes, so goes the subsequent displacements $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$ and their associated energies. This means that, from the perspective of $\mathbf{d}_1$, an entity (e.g. a "particle") that is constructed from one or more of the components $\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, or $\mathbf{d}_3$ will be distributed as per its $\mathbf{d}_0$ component --- uniformly across ordinary space.

Of course, such "smearing out" across space of an entity's location is a well-known, but enigmatic, phenomenon of quantum mechanics. It now has the following basic explanation within the present model: an entity's $\mathbf{d}_0$ component is independent of ordinary space, and so the entity must manifest uniformly throughout that space. (Later on --- in section 4.13 --- we explore how such an entity may then go on to acquire, e.g., a definite position within ordinary space.)

So, in summary, the view of $\mathbf{d}_0$ from the perspective of $\mathbf{d}_1$ does the following: (a) It constructs ordinary space (isotropic and homogeneous), and (b) it takes *all* energy within the system and spreads it uniformly throughout ordinary space, thereby producing uniform *fields*, filling all of space, for each of the $\mathbf{d}_k$ energies ($k = 0, 1, 2, 3$) --- and likewise for the related energies E_1, E_2, E_3, and E_4.

Note that the *uniform* distribution of $\mathbf{d}_0$ energy throughout ordinary space might strictly apply *only* to that energy which comes into the system *after* the advent of $\mathbf{d}_1$ (with the concomitant advent of time and ordinary space itself). *Prior to* the advent of $\mathbf{d}_1$, the $\mathbf{d}_0$ energy may be distributed (perhaps nonuniformly) along the *length* of $\mathbf{d}_0$ (as alluded to at the beginning of section 4.1). Given its priority, this linear distribution might manifest *axially* at the advent of ordinary space, and remnants of it might survive the inflation process, thereby imprinting some large-scale anisotropy on the cosmic microwave background (CMB) --- perhaps yielding, e.g., the so-called "axis of evil" [8], [9].

We can thus divide the production and distribution of $\mathbf{d}_0$ energy into two logical phases, or epochs: (1) the epoch *prior* to the advent of $\mathbf{d}_1$, in which $\mathbf{d}_0$ energy may be distributed along the length of $\mathbf{d}_0$, and (2) the epoch *after* the advent of $\mathbf{d}_1$, in which $\mathbf{d}_0$ energy is distributed uniformly throughout the volume d_0^3 of ordinary space.

4.4.2 Small-scale distribution of energies at level 2 and above

Recall that both time and h exist at level 2 (factor 4). The presence of time means that the input of $\mathbf{d}_1$ energy into level 2 can be, and we assume *is*, time-dependent and time-limited --- and thus *finite*. So the $\mathbf{d}_1$ process inputs a finite amount of energy into level 2. Furthermore, we expect the presence of h to partition this energy into smaller bits or chunks, yielding a *multiplicity* of what we will generically refer to as *level-2 objects* or entities. Due to their $\mathbf{d}_1$ component, which is logically nested within $\mathbf{d}_0$, the level-2 objects will see themselves as nested/enveloped/contained/embedded within the three-dimensional space of $\mathbf{d}_0$ (as seen from the perspective of $\mathbf{d}_1$) --- that is, they will see themselves as embedded within ordinary space (S^3_{01}).[3] Lastly, since *time* exists at level 2, we assume (as per special relativity) that the level-2 objects possess *mass*.

The same considerations apply at level 3. The presence of time means that the $\mathbf{d}_2$ process can (and, we assume, *does*) input a *finite* amount of $\mathbf{d}_2$ energy into level 3, and the presence of *h* partitions this energy into a multiplicity of *level-3 objects*. And, as with the level-2 objects, their $\mathbf{d}_1$ component will cause these level-3 objects to see themselves as embedded within ordinary space. Moreover, the presence of *time* at level 3 means that the level-3 objects possess mass. And likewise for $\mathbf{d}_3$, $\mathbf{d}_4$, etc., and their corresponding energies at levels 4 and above.

As indicated above, the advent of $\mathbf{d}_1$ yields *h*, which brings about small-scale nonuniformities (i.e. chunkiness) in the distribution of energies at level 2 and above. In addition, we note that the advent of $\mathbf{d}_1$ also brings about *inflation* (section 3.6), by which these nonuniformities can then come to be imprinted on the CMB.

In summary: Whereas, the view of $\mathbf{d}_0$ from the perspective of $\mathbf{d}_1$ causes all energies in general to be distributed uniformly throughout ordinary space, the presence of *h* causes the distribution of energies *at level 2 and above* --- i.e. $\mathbf{d}_1$ energy, $\mathbf{d}_2$ energy, etc. --- to be granular or chunky on the small scale. This yields a multiplicity of objects at level 2 and above, each of which see themselves as embedded *within* ordinary space.

4.4.3 Further aspects of $\mathbf{d}_0$ energy

Unlike the situation just described for level 2 and above, the *absence* of *h* at level 1 (factor 3) means that $\mathbf{d}_0$ energy (which is input into level 1) *cannot* be broken into chunks --- and so it constitutes a *single*, continuous entity; i.e., the distribution of $\mathbf{d}_0$ energy throughout ordinary space is *completely* uniform, on both the large *and* small scales. In addition, since time does *not* exist at level 1, we assume that this single entity at level 1 is *massless*.

Recall again that the $\mathbf{d}_0$ process inputs $\mathbf{d}_0$ energy into *level 1*, but *time* is native to *level 2* (factor 4). Thus the $\mathbf{d}_0$ process is *prior to* time. By postulate 4, this means that the $\mathbf{d}_0$ process is *independent of time*, and is therefore a *continual* process --- thereby yielding a *stream* of $\mathbf{d}_0$ energy into level 1 that never stops, and so must be happening right now. Consequently, the quantity of $\mathbf{d}_0$ energy is *always* increasing. Moreover, since $\mathbf{d}_0$ (as seen by $\mathbf{d}_1$) *is* ordinary space, then it is clear that $\mathbf{d}_0$ energy is just the energy of space itself. Indeed, an increase in $\mathbf{d}_0$ energy may be associated with an increase in the *length* of $\mathbf{d}_0$, and thus with an increase in d_0^3 (the size/volume of the physical universe). Hence, an always-increasing $\mathbf{d}_0$ energy should yield a *continual expansion of ordinary space*.

3 A level-2 object's perspective --- of being nested/embedded within ordinary space --- might thereby establish its viewpoint as an idiosyncratic "special location" within ordinary space. Nevertheless, it should still see the ordinary space in which it is embedded as isotropic and homogeneous, as per the results of section 3.4.

As concluded above in this section, and in section 4.4.1, the $\mathbf{d}_0$ process must (in the second epoch) distribute its $\mathbf{d}_0$ energy *uniformly* throughout space. Since this process is also independent of time, then it is *constant in time*. Thus, the continual influx of $\mathbf{d}_0$ energy into the system via the $\mathbf{d}_0$ process yields an influx of energy per unit volume of space that is uniform throughout space, and constant in time. In other words, the $\mathbf{d}_0$ process yields a *cosmological constant*.

Taken all together, the above results suggest that we interpret $\mathbf{d}_0$ energy to be the phenomenon known as *dark energy* [10]; that is,

$$\mathbf{d}_0 \text{ energy} = \text{dark energy.}$$

Moreover, since $\mathbf{d}_0$ energy is a *level-1* phenomenon, but *h* only becomes operant at *level 2* (factors 3 and 4), then dark energy is prior to --- and thus independent of --- *h* and quantum mechanics, and so *cannot* be a quantum vacuum energy. This conclusion can also be deduced from the result (in section 4.2) that $\mathbf{d}_0$ energy is a form of E_1 energy, plus the result (in section 4.3) that quantum vacuum energy is *not* E_1 energy.

4.4.4 Further aspects of $\mathbf{d}_2$ energy distribution (at level 3)

As stated in section 4.4.2, the presence of *h* at level 3 partitions the $\mathbf{d}_2$ energy into a multiplicity of smaller chunks --- the level-3 objects. Furthermore, we determined that these objects have *mass*.

In section 3.2 we found that the three-dimensional spaces S^3_{02} and S^3_{12} come into existence at level 3, and that the latter is nested within the former, which in turn is nested within ordinary space, S^3_{01} (factor 5). Thus, S^3_{12} is a subset of S^3_{02}, which is a subset of S^3_{01} (ordinary space). We now ask: with respect to a level-3 object, *where* is the S^3_{02} space located?

In section 4.4.2 we found that a level-3 object sees itself as being embedded within ordinary space, S^3_{01}. Since ordinary space is prior to --- and thus independent of --- S^3_{02}, then the space that a level-3 object sees itself embedded in is independent of, and thus *outside the scope of*, the (subsequent) S^3_{02} space. This means that the S^3_{02} space must be *internal to* (i.e. confined or compacted *within*) the level-3 object. And since the S^3_{12} space is nested within S^3_{02}, then it too is confined/compacted *within* the level-3 object. A level-3 object thus partitions ordinary space (S^3_{01}) into *two* zones: an *outside* or exterior zone, which it sees itself as embedded in; and an *inside* zone, which corresponds to the restricted scope of the S^3_{02} space, and forms the *interior* of the level-3 object. In short, a level-3 object has *internal* spaces, which opens the possibility for internal *structure*.

Since S^3_{01} and S^3_{02} are three-dimensional spatial modes of the displacement $\mathbf{d}_0$, which is independent of *h*, then we assume that (within their respective scopes) each of those spaces manifests as a *single*, continuous, three-dimensional space (i.e. having no discontinuity or chunkiness). On the other hand, since S^3_{12} is a spatial mode of the displacement $\mathbf{d}_1$, for which *h is* operant, then let us assume that its continuity may be broken. In particular, suppose that S^3_{12} is broken into *three, discrete*, one-dimensional spaces --- i.e. three discrete degrees of freedom.

It is then reasonable to assume that at least some of the $\mathbf{d}_2$ energy of a level-3 object will be distributed into *each* of these three, discrete, degrees of freedom for S^3_{12} --- resulting in a *triplet* of energy nodes or particles *within* the object. Consequently, each level-3 object will have *internal structure* that includes a triplet of subparticles that are *confined* within the object. We interpret, therefore, that level-3 objects are the particles known as *baryons*, and their three subparticles are the objects known as *quarks*. In this way, the present model may account for the existence of baryonic quarks, and also their *confinement* within the baryons.

4.4.5 Substructure at level 4

Since everything at level 3 is inherited by level 4, then level-4 objects would, like level-3 objects, also have a substructure of three discrete particles or quarks. However, in section 3.2 it was stated that level 4 generates three new, three-dimensional spaces, which were denoted as S^3_{x3} ($x = 0, 1, 2$), and that these spaces are internal to S^3_{02} and S^3_{12}. It seems likely, therefore, that the three subparticles/quarks within level-4 objects would themselves contain internal structure (whereas the quarks at level 3 would have no internal structure).

4.4.6 The extra single dimensions at level 3 and above

The extra single dimensions S^1_{20} and S^1_{21} that are native to level 3 are prior to S^3_{02} and S^3_{12}, but subsequent to ordinary space, S^3_{01}. Objects at level 3 (and above) will therefore see those single dimensions as *internal*; whereas S^3_{02} and S^3_{12} will see them as being operant everywhere within their three-dimensional spaces (just as ordinary time is operant everywhere within ordinary space --- section 3.5). Thus, S^1_{20} and S^1_{21} might produce something akin to extra "time" dimensions that would apply to the internal three-dimensional spaces of objects at level 3 and above (e.g. baryons).

4.5 Some particles of system P

We have identified the objects at level 3 as the baryons, and the single entity at level 1 as dark energy. What about the objects at level 2?

We first note that there are no internal spaces at level 2 (in contrast to level 3), so level-2 objects have no internal structure; i.e. they are *structureless*. Second, as concluded in section 4.4.2, the level-2 objects have *mass*. We therefore identify the objects at level 2 as the *leptons*. Fig. 2 illustrates the identification of entities at different levels with known (or, in the case of dark energy, *suspected*) entity/object/particle classes.

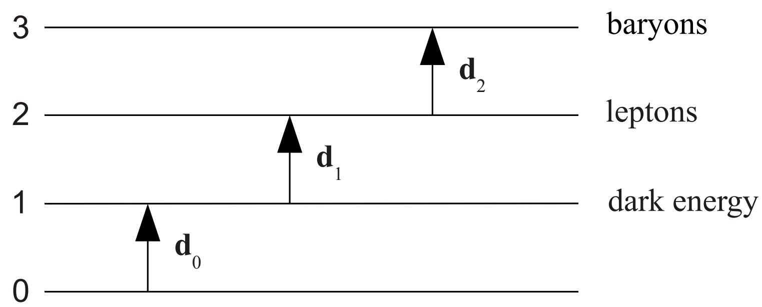

Fig. 2 Identification of the level-1 entity as dark energy, the level-2 objects as leptons, and the level-3 objects as baryons.

4.5.1 Associating particle properties with displacements

We have already established that, in constructing the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$), it is the displacement $\mathbf{d}_0$ that inputs E_1 energy into the system. We therefore associate E_1 energy with $\mathbf{d}_0$.

The main difference between a lepton and a baryon is that the latter has the property known as *baryon number* (or baryon *charge*), and the former does not. In the present model, the main difference between a level-2 object and a level-3 object is that the latter has the displacement $\mathbf{d}_2$, whereas the former does not. We therefore associate baryon number/charge with $\mathbf{d}_2$.

Likewise, a main difference between dark energy and leptons is that the latter possess the properties known as *lepton number* (or lepton *charge*), mass, and possibly electric charge; whereas the former presumably possesses none of those properties. In the present model, the main difference between level-1 and level-2 entities is that the latter have the displacement $\mathbf{d}_1$, whereas the former does not. We therefore associate lepton charge, electric charge, and mass with $\mathbf{d}_1$.

4.6 Analogy of system P with biological genetics

In constructing the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$), by analogy with biological genetics we might consider the set of displacements that are operant at a given level to be the "genome" for an entity/object/particle class or "genus" at that level. Thus, the genome for an entity at leve1 0 is { }; the genome for dark energy at level 1 is $\{\mathbf{d}_0\}$; the genome for leptons at level 2 is $\{\mathbf{d}_0, \mathbf{d}_1\}$; and the genome for baryons at level 3 is $\{\mathbf{d}_0, \mathbf{d}_1, \mathbf{d}_2\}$. We might think of the individual displacements $\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, etc., within the genomes as "codons", or as simple "genes" for the particle properties that we have roughly associated with them; e.g., $\mathbf{d}_0$ is the gene for energy; $\mathbf{d}_1$ is the gene for electric charge and lepton number; and $\mathbf{d}_2$ is the gene for baryon charge. Moreover, epigenetic analogies may also apply. For example, we may think of the lepton-number characteristic of $\mathbf{d}_1$ as being "turned on" at level 2, allowing its expression there, but "turned off" at level 3, suppressing its expression.

The object classes and genomes at each successive level constitute "generations" of entities. Thus, dark energy at level 1 is the first-generation entity; leptons at level 2 are entities of the second generation; and baryons at level 3 are entities of the third generation. Each such generation inherits the genes (indeed, the complete genome) of the prior generation.

We may also think of the energy types --- E_1, E_2, E_3, etc. --- as having genomes, which correspond to the displacements that are operant at their *native* levels. Thus E_1 has the genome $\{\mathbf{d}_0\}$; E_2 has the genome $\{\mathbf{d}_0, \mathbf{d}_1\}$; E_3 has the genome $\{\mathbf{d}_0, \mathbf{d}_1, \mathbf{d}_2\}$; and so on.

4.7 Real and virtual particles

Let us define a *real* object/particle as one whose energy enters the system in the normal way: via the displacement $\mathbf{d}_0$, native to level 1, as E_1 energy. As discussed earlier, in constructing the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$), some of this E_1 energy at level 1 is further displaced up the levels, thereby also becoming E_2 energy, E_3 energy, etc. --- but, due to its provenance, always retaining its essential nature as "E_1 energy". This process yields *real* entities/particles at each level: dark energy at level 1; real leptons at level 2; and real baryons at level 3.

The other way that energy enters the system is (as described in section 4.3) via the quantum of action, h, which depends on $\mathbf{d}_0$ *and* $\mathbf{d}_1$, and is thus native to level 2. This is the quantum vacuum energy, or energy of quantum fluctuations, which produces *virtual* particles. Since the entry of this energy into the system *bypasses* the normal $\mathbf{d}_0$ process, it is *not* E_1 energy, and cannot produce dark energy. Rather, such quantum vacuum energy can only produce E_j-energy forms (and corresponding virtual particles) that are native to level 2 and above --- i.e. E_2 energy (virtual leptons), E_3 energy (virtual baryons), etc.[4] Although virtual particles do not contain E_1 energy, they are *still* dependent on $\mathbf{d}_0$, and so it seems appropriate to include the $\mathbf{d}_0$ component in their genomes. As such, the genomes for virtual leptons and virtual baryons will be denoted in the same way as their real counterparts; i.e. as $\{\mathbf{d}_0, \mathbf{d}_1\}$ and $\{\mathbf{d}_0, \mathbf{d}_1, \mathbf{d}_2\}$, respectively.

4.8 Fundamental interactions

The displacements that we have discussed so far may be described as *forward* displacements, since (as described in postulate 1) they go from a prior level to a subsequent level (i.e. they are directed *away* from level 0). We associated these displacements with the input of energy into higher/subsequent levels. We now want to introduce the concept of *reverse* or *backward* displacement, which goes in the opposite direction: from a subsequent level to a prior level (i.e. *toward* level 0). Specifically, I propose that each forward displacement $\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, etc., has a corresponding backward displacement, which we denote as $-\mathbf{d}_0$, $-\mathbf{d}_1$, $-\mathbf{d}_2$, etc., respectively.

Basically, for an object that has $\mathbf{d}_k$ in its genome (and thus also has E_{k+1} energy --- except virtual particles, which have no E_1 energy), we define $-\mathbf{d}_k$ as "the backward

4 The origin of photons, gluons, W/Zs, and gravitons is explained in section 4.8.

displacement of E_{k+1} energy onto level k" (for k = 0, 1, 2, 3). That is, such a backward displacement, $-\mathbf{d}_k$, takes E_{k+1} energy --- which is *above* level k --- and places it *at* level k, yielding an object/particle at that level. More generally, a *sequence* of backward displacements, denoted as ($-\mathbf{d}_k$, $-\mathbf{d}_{k-1}$, ...) can take E_{k+1} energy and place it at any prior level (k, k-1, ..., 0). Thus, for example, a level-2 object with genome $\{\mathbf{d}_0, \mathbf{d}_1\}$ may utilize the backward displacement $-\mathbf{d}_1$ to place E_2 energy onto level 1, yielding an object at that level.

Backward displacement in the present model is in some ways similar to *projection* as we know it from ordinary geometry. Consider a three-dimensional sphere for example: it becomes a *two*-dimensional circle when projected onto the x-y plane; and the circle becomes a *one*-dimensional line when projected onto the x-axis. So, with each "backward" projection the space dimensions of the object are reduced by one. Similar things happen with backward *displacement* in the present model (as described below).

In addition to forward and backward displacements, let us also define a *lateral* or *intra*level displacement of E_j energy, which places that energy onto E_j's *native* level (which, it may be recalled, is level j), thereby yielding an object/particle at that level. Backward and lateral/intralevel displacements may be classified together as *nonforward* displacements.[5]

My current understanding of the model is that, when E_j energy is laterally displaced onto level j, it *retains* its designation as "E_j energy"; but when it is backward displaced onto level j - 1 (thereby losing its $\mathbf{d}_{j-1}$ displacement), it *loses* its designation as "E_j energy". However, as we will see, the strong interaction may be more nuanced than that.

The basic theme below is that *all* fundamental interactions are due to nonforward displacements of E_j energy onto a prior level, or onto its native level, j.

4.8.1 The electromagnetic interaction

Objects at level 2 or above (e.g. leptons and baryons, with genomes $\{\mathbf{d}_0, \mathbf{d}_1\}$ and $\{\mathbf{d}_0, \mathbf{d}_1, \mathbf{d}_2\}$, respectively), whether real or virtual, have the displacement $\mathbf{d}_1$ in their genomes, and have E_2 energy. We now ask, what happens when E_2 energy, associated with these objects' $\mathbf{d}_1$ component, is backward displaced onto level 1 (the operation that we have denoted as $-\mathbf{d}_1$)? Since E_2 energy has the genome $\{\mathbf{d}_0, \mathbf{d}_1\}$, and loses its $\mathbf{d}_1$ component in the backward displacement ($-\mathbf{d}_1$), we could denote the genome for the resulting level-1 object as $\{\mathbf{d}_0\}$. But that would confuse it with the genome for dark energy, and also obscure the object/energy's *history* (of, inter alia, being the product of a *backward* displacement). A better way to denote its genome is therefore $\{\mathbf{d}_0, -\mathbf{d}_1\mathbf{d}_1\}$. This object has energy, but no electric charge (due to the net absence of $\mathbf{d}_1$ in its genome), and (due to the absence of $\mathbf{d}_1$/time) is massless. Its "source", if you will, is $\mathbf{d}_1$, which we have associated with electric charge. We interpret, therefore, that the object denoted by the genome $\{\mathbf{d}_0, -\mathbf{d}_1\mathbf{d}_1\}$, resulting from backward displacement of E_2 energy onto level 1, is the *photon*. So, in this sense, we say that *the photon is a level-1 object* that is produced by *backward* displacement (in contrast to dark energy, which is a level-1 entity produced by *forward* displacement). Furthermore, we interpret that the backward displacement of E_2 energy

5 These new types of displacement will later be incorporated into a *fifth* postulate.

onto level 1 (i.e. -$\mathbf{d}_1$) is just the *electromagnetic interaction* (actually, it is the *emission* phase of that interaction; the absorption phase will be discussed later). In general, then, it is suggested that backward displacement is responsible for at least some of the fundamental interactions.

At level 2 the dimensionality of $\mathbf{d}_0$ (with respect to $\mathbf{d}_1$) is 3, and the dimensionality of $\mathbf{d}_1$ (with respect to $\mathbf{d}_0$) is 1 (i.e. the dimensions of ordinary space and time, respectively). When E_2 energy is backward displaced onto level 1 (via the operation -$\mathbf{d}_1$), the dimension of time (associated with $\mathbf{d}_1$) vanishes to zero. Likewise, the component of $\mathbf{d}_0$ parallel to $\mathbf{d}_1$ also vanishes, leaving only *two* space dimensions (which may thus be called the *residual* dimensions, or the *residual 2-space*, of $\mathbf{d}_0$ with respect to $\mathbf{d}_1$), both of which are orthogonal to $\mathbf{d}_1$. In other words, the backward displacement of E_2 energy onto level 1 produces an object for which the time dimension does not exist, and whose space dimensions are reduced from three to two --- which agrees with the results implied by special relativity for the photon, further supporting our interpretation that photons are the result of backward displacement of E_2 energy onto level 1.

Light (i.e. electromagnetic radiation) is thus energy that starts out at level 2 (or above) and is backward displaced onto level 1 (where time does not exist). Its origin at level 2 or above (where time *does* exist) endows this energy with a *history*, an aspect of which is its exposure to h, which (I propose) endows light energy with its quantum properties. Dark energy, in contrast, is a *strictly* level-1 entity/phenomenon; so we can say that *it is energy without a history*. Its lack of a history at level 2 or above means that dark energy has never been exposed to h, and so it is not quantized, and has no quantum properties (e.g., as determined earlier, it has no quantum chunkiness).

It seems, then, that the quantum properties and two-dimensional space of light/photons may all be residual aspects (or, if you will, *residues*) that stem from the energy's history at level 2 or above.

4.8.2 The strong interaction

Objects at level 3 or above (e.g. baryons, with genome {$\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$}), whether real or virtual, have the displacement $\mathbf{d}_2$ in their genome, and have E_3 energy. We now ask, what happens when E_3 energy, associated with these objects, is backward displaced onto level 2 (the operation that we have denoted as -$\mathbf{d}_2$)?

As stated earlier, when $\mathbf{d}_1$ is related to $\mathbf{d}_2$ the dimensionality of the former is 3 (i.e. S^3_{12}), and the dimensionality of the latter is 1 (i.e. S^1_{21}). When E_3 energy is backward displaced onto level 2, the one dimension associated with $\mathbf{d}_2$ vanishes to zero, and the three dimensions associated with $\mathbf{d}_1$ are reduced to *two*. Since we earlier interpreted that, at level 3 (or above), the three, one-dimensional spaces associated with $\mathbf{d}_1$ (from the viewpoint of $\mathbf{d}_2$) were responsible for the *triple*-quark substructure of baryons, I now propose that the reduction of these dimensions down to two --- when E_3 energy is backward displaced onto level 2 --- is responsible for the production of objects with a *double*-quark substructure. Consequently, we interpret that the objects produced by backward displacement of E_3 energy onto level 2 are the *mesons* (which, indeed, are thought to have a double-quark --- actually, quark-antiquark --- substructure). So, in this sense, *the mesons are level-2 objects*, whose genome may be denoted as $\{\mathbf{d}_0, \mathbf{d}_1, -\mathbf{d}_2\mathbf{d}_2\}$ --- which comports with the mesons possessing energy, electric charge, mass, and zero net baryon charge.

We can therefore think of mesons as level-2 objects that contain remnants of *level-3-type* substructure (i.e. the two quarks). This is probably allowed by the nesting rule, since the (subsequent) level-3-type substructure is embedded/contained within the (prior) level-2 object.

In the above description (of backward displacement of E_3 energy onto level 2), we utilized the residual 2-space of $\mathbf{d}_1$ with respect to $\mathbf{d}_2$ (to account for the double-quark substructure of mesons), but we neglected to mention another such space that arises in this process: the residual 2-space of $\mathbf{d}_0$ with respect to $\mathbf{d}_2$; i.e. the 2-space that remains when, due to backward displacement of E_3 energy onto level 2, the component of $\mathbf{d}_0$ in the direction of $\mathbf{d}_2$ vanishes. We have thus identified *three* residual 2-spaces: the residual 2-space of $\mathbf{d}_0$ with respect to $\mathbf{d}_1$, which may be referred to as the *first* residual 2-space; the residual 2-space of $\mathbf{d}_0$ with respect to $\mathbf{d}_2$, which may be referred to as the *second* residual 2-space; and the residual 2-space of $\mathbf{d}_1$ with respect to $\mathbf{d}_2$, which may be referred to as the *third* residual 2-space. The numbering/ranking of these residual spaces reflects their order of priority. Given such priority relations, together with the nesting rule, we conclude that, where applicable: the third residual 2-space is nested/encapsulated/confined within the second, and the second is nested/confined within the first.

When E_3 energy is backward displaced onto level 2, only the second and third residual 2-spaces are applicable (since $\mathbf{d}_1$ is *operant* at level 2, and thus the space of $\mathbf{d}_0$ with respect to $\mathbf{d}_1$ --- i.e. *ordinary* space --- is fully three dimensional). By the priority relations established above, the third residual 2-space, which yields the double-quark substructure of mesons, would be *confined* within the second --- a result which might explain the confinement of quarks within mesons.

Consider now a process in which E_3 energy is backward displaced onto *level 1*, via the operations $-\mathbf{d}_2$ and $-\mathbf{d}_1$ --- a *sequence* of backward displacements which may be denoted by $(-\mathbf{d}_2, -\mathbf{d}_1)$. The result of this process is an object at level 1 whose genome may be written as $\{\mathbf{d}_0, -\mathbf{d}_1\mathbf{d}_1, -\mathbf{d}_2\mathbf{d}_2\}$ --- which therefore is massless (due to the absence of $\mathbf{d}_1$), and possesses zero electric, lepton, and baryon charges. I propose that this object is the *gluon*.

In this gluon-production process, the third residual 2-space would cease to exist (since $\mathbf{d}_1$ is not operant at level 1). So whatever is left over from the backward-displacement sequence (double color charge?) would be confined within the *second* residual 2-space, which would be confined within the first. This result might explain the confinement of gluons and their color charges.

In summary, we interpret that the strong interaction as mediated by mesons is the result of backward displacement of E_3 energy onto level 2; and the strong interaction as mediated by gluons is the result of a sequence of backward displacements, $(-\mathbf{d}_2, -\mathbf{d}_1)$, of E_3 energy onto level 1.

4.8.3 The weak interaction, and electroweak unification

The weak interaction is known to be mediated by the W and Z bosons. Given that the W and Z possess mass, have zero baryon number, and have no internal structure (as far as we know), it follows that they are *level-2* objects in the present model. Thus the weak interaction involves the displacement of energy onto *level 2*, which thereby yields objects/particles at that level (i.e. the W and Z). We know that leptons participate in the weak interaction, and (according to the present model) that they are also level-2 objects, having the genome $\{\mathbf{d}_0, \mathbf{d}_1\}$, thereby possessing E_2 energy and (for a *real* lepton) E_1 energy. Since leptons and the W/Z are all level-2 objects, then (unlike the interactions described above) the weak interaction cannot be attributed to *backward* displacement --- of either the leptons' E_1 energy or its E_2 energy (since such backward displacements would yield objects at levels 0 and 1, respectively --- i.e. *not* at level 2, where the W and Z reside). Rather, the weak interaction must be attributable to a lateral/*intra*level displacement, of either E_1 or E_2 energy. But E_1 is native to level 1, so a *lateral* displacement of E_1 energy would place the energy at *level 1*, not level 2. So it seems that we must attribute the weak interaction to a lateral/intralevel displacement of E_2 energy.

Since the *electromagnetic* interaction has *also* been attributed to a nonforward displacement of E_2 energy, then we can say that the electromagnetic and weak interactions have the *same* source --- $\mathbf{d}_1$ (or its associated E_2 energy). Consequently, as we have associated electric charge with $\mathbf{d}_1$, it seems that we must also associate the *weak charge* with $\mathbf{d}_1$. As such, the present model offers an explanation for the known "electroweak unification": the electromagnetic and weak interactions are related or "unified" because they *both* stem from the nonforward displacement of E_2 energy --- where the former interaction is attributed to *backward* displacement of such energy (i.e. onto level 1), and the latter interaction is attributed to *lateral* displacement of such energy (i.e. *within* level 2). In addition, the lateralness (thus, possibly, *handedness*) of an *intralevel* displacement might explain why the weak interaction violates left-right symmetry, or parity.

Although it may be useful at some future time to develop a special notation to indicate in their genomes that the W and Z particles are products of *lateral* displacement of E_2 energy, for now we will just denote them as having the same genome as level-2 objects that are produced by *forward* displacement --- i.e. $\{\mathbf{d}_0, \mathbf{d}_1\}$.

4.8.4 The gravitational interaction

Following the pattern of the interactions above, we should attribute gravity to a nonforward displacement of one of the E_j energies ($j = 1, 2, 3, 4$). Since dark energy is a source of gravity, and is a *level-1* phenomenon, then the energy type to which we attribute gravity must be present/available/operant at level 1 --- a condition that *only* E_1 energy satisfies. So it follows that we should attribute gravity to a nonforward displacement of E_1 energy: either backward displacement onto level 0, *or* lateral/intralevel displacement onto level 1. But which one? For reasons to be provided in section 4.14, we choose the latter --- that is, we attribute the gravitational interaction to the *lateral/intralevel* displacement of E_1 energy onto level 1. This means that the "graviton" (in common with the photon and the gluon) is a *level-1* object that is produced by nonforward displacement. Thus, the strong, electromagnetic, and gravitational interactions all utilize nonforward displacement onto level 1 (the strong interaction also utilizes nonforward displacement onto *level 2*, as described above).

Our model for gravity yields the following results and explanations concerning that interaction.

- **Cosmological constant**: Since E_1 energy is the source of gravity, and since (as determined in section 4.3) quantum vacuum energy is *not* E_1 energy, then the energy of quantum vacuum fluctuations is *not* a source of the gravitational interaction (i.e. it does not gravitate). Therefore, quantum fluctuations cannot contribute to the cosmological constant, Λ.

  Or, putting this argument more figuratively, we might say: Energy that enters the system through the "front door" (i.e., in the normal way, via $\mathbf{d}_0$ at level 1) inherits the mantle of "E_1 energy", and is thereby a source of the gravitational interaction; but energy that *sneaks in* through a "side door" (i.e. via h, at level 2 or above) does *not* inherit the mantle of "E_1 energy", and therefore is *not* a source of the gravitational interaction --- and so cannot contribute to the cosmological constant. (This suggests that we might also label E_1 energy as *normal*, *ordinary*, or *classical* energy.)

  As far as we can tell from the present model, then, the only contribution to Λ comes from the (non-quantum-mechanical, non-zero-point) $\mathbf{d}_0$ energy that the $\mathbf{d}_0$ process continually inputs into level 1, and which we have associated with the creation and expansion of ordinary space (section 4.4.3). By eliminating contributions to Λ from quantum fluctuations, the present model thereby averts the "cosmological constant problem" [11], and may thus explain the observed small value of that constant.

  Note that, although quantum fluctuations do not produce E_1 energy (which is native to level 1), and thus are not a source of gravity, our earlier results indicated that such fluctuations *can* produce E_j-energy forms (and corresponding virtual particles) that are native to level 2 and above; i.e. E_2 energy (virtual leptons), E_3 energy (virtual baryons), etc. These E_j-energy forms can then be nonforwardly displaced, yielding (for E_2 energy) the electromagnetic and weak interactions, and (for E_3 energy) the strong interaction. The electromagnetic interaction, due to the backward displacement of E_2 energy for such virtual particles, can presumably then yield the Casimir effect and the Lamb shift.

  In summary, we might say that quantum vacuum energy (and thus virtual particles) can emitate[6], weakitate, and strongitate --- but cannot gravitate.

- **Nonquantization** (or, why gravity seems to defy attempts at quantization): Since the source of gravity is E_1 energy (which is native to level 1), and since the quantum of action h is native to level 2, then the basis for the gravitational interaction is *prior* to, and thus independent of, h; and so gravity is not

6 Where "emitate" might also have been written as EMitate, with obvious meaning in this context.

fundamentally quantum mechanical.[7] Or, in more figurative language, we might say: The basic ingredient for gravity (E_1 energy) is "up and running" at level 1, before quantum mechanics (i.e. h) "gets its boots on" at level 2.

Furthermore, given our result that quantum fluctuations cannot contribute to Λ, then Λ appears also to be independent of h, and thus independent of quantum mechanics. So, as far as we can tell from the present model, gravity is *completely* independent of h and quantum mechanics --- perhaps eliminating the need for a quantum theory of gravity.[8]

- **Universality** (almost): Recall that, in constructing the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$), *all* of the energy that is involved --- in whatever forms it might take (i.e. E_1 energy, E_2 energy, E_3 energy, etc.) --- shares the provenance of entering the system via the $\mathbf{d}_0$ portal, and is therefore "E_1 energy". Consequently, the "lateral/intralevel displacement of E_1 energy within level 1" is a *universal* characteristic of all these energy forms and their associated objects/particles (e.g. real leptons, real baryons, etc). In other words, *all* of the energy associated with these things will laterally displace onto level 1, thereby making them sources of gravity. This would seem to account for the "universal" nature of the gravitational interaction.

  Of course, this "universality" of gravity comes with the one exception, described above, that quantum vacuum energy, due to its provenance of entering the system at level 2 or above, thus *bypassing* the $\mathbf{d}_0$ process, is not E_1 energy, and is therefore *excluded* as a source of gravity. So provenance matters.

4.8.5 Other possible fundamental interactions

Given our characterization of fundamental interactions as being the result of "nonforward displacement of E_j energy", then the case for which $j = 4$ presents the possibility for new interaction types, via (a) backward displacement of E_4 energy, and (b) lateral/intralevel displacement of E_4 energy (onto level 4). Likewise, for $j = 3$, there might be an interaction type that is due to intralevel displacement of E_3 energy (onto level 3). However, due to the confinement that occurs for E_3 energy, E_4 energy, etc., it is possible that such interactions would not manifest outside of the compacted spaces of level 3 and above, which could explain why such novel interactions (if they exist) have not yet been identified. And, for the supposed interaction resulting from lateral displacement of E_3 energy onto level 3, it is possible that any of its effects which *do* manifest have been confused/conflated with aspects of the strong interaction.

Finally, there is "backward displacement onto *level 0*", which will be taken up in sections 4.13.3 and 4.13.5.

7 It should thus be apparent that use of the term "graviton" in this paper does not imply any bias towards a *quantized* conception of gravity.

8 Some articles that question the need for quantum gravity are [12] and [13].

4.9 Interaction examples

In our descriptions of fundamental interactions above we actually only provided an account of the first *half* of some interactions: *emission* of the mediating particle from its source, by either backward or lateral displacement. In the examples below, we give more complete descriptions by also including (where appropriate) the *absorption* of the mediating object.

4.9.1 Electromagnetic

Consider the electromagnetic interaction between an electron and a proton, in which the electron emits a photon, and the proton absorbs it. Our description of the electromagnetic interaction in section 4.8.1 accounted only for the first half of that interaction: emission of the photon by the electron, which we described as the backward displacement, onto level 1, of E_2 energy. The second half of the interaction --- absorption of the photon by the proton --- can be accounted for as follows: the photon energy, at level 1, is *forward* displaced[9] from level 1 (i.e. along the line of $\mathbf{d}_1$), thereby becoming associated with the *proton's* $\mathbf{d}_1$ component. (Of course, this means that *only* objects *having* a $\mathbf{d}_1$ component in their genome can participate in the electromagnetic interaction; which, again, indicates that electric charge is associated with $\mathbf{d}_1$.)

4.9.2 Weak

Consider the decay of a neutron into a proton via the weak interaction, mediated by emission of a W^- particle (so-called beta decay). Since the neutron is a *level-3* object, and the W^- is a *level-2* object, doesn't this process involve *backward* displacement onto level 2 (i.e. not *intralevel* displacement, *within* level 2 --- the modus operandi that we determined above for the weak interaction)? No; as with the leptons at level 2, we interpret that the neutron's participation in the weak interaction is due to *intralevel/lateral* displacement of E_2 energy. But, to understand this, we must recall that E_2 is *native* to level 2, so that a lateral displacement of E_2 energy associated with the neutron will be placed onto *level 2* --- not level 3 (the level of the neutron itself).

Beta decay is thus described as follows: E_2 energy associated with the neutron is *laterally* displaced onto/within level 2, as the W^- particle --- thereby transforming the neutron into a proton.

As another example, the weak interaction of a proton (emitter) and electron (absorber), mediated by exchange of a Z particle, is described as follows: E_2 energy associated with the proton is laterally displaced onto level 2 (as the Z particle), which then becomes associated with the *electron's* $\mathbf{d}_1$ component.

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9 This kind of "forward" displacement is different from the forward displacements that *create* the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$) for system P. This will be clarified as we go along, and then summarized/formalized in postulate 5.

4.9.3 Strong

The strong interaction between *nucleons A* (emitter) and *B* (absorber), mediated by exchange of a meson, can be described in the following way: E_3 energy associated with *A* is backward displaced onto level 2, as a meson. This meson energy is then forward displaced along the line of $\mathbf{d}_2$, thereby becoming associated with *B's* $\mathbf{d}_2$ component.

The strong interaction between *quarks A* and *B*, mediated by exchange of a gluon, can be described as follows: E_3 energy associated with *A* is backward displaced onto level 1 (as a gluon), via the sequence ($-\mathbf{d}_2$, $-\mathbf{d}_1$). This gluon energy is then forward displaced along the lines of $\mathbf{d}_1$ and $\mathbf{d}_2$ --- i.e. via the sequence ($\mathbf{d}_1$, $\mathbf{d}_2$) --- thereby becoming associated with *B's* $\mathbf{d}_2$ component.

4.9.4 Gravitational

Consider the *gravitational* interaction between *A* and *B*, which are two (real) objects/particles/entities at level 1 or above (so that each has a $\mathbf{d}_0$ component), and where *A* is the emitter, and *B* is the absorber. First, E_1 energy associated with *A* is laterally displaced onto level 1 (as the graviton), which then becomes associated with *B's* $\mathbf{d}_0$ component.

Note that, as worded above, the criterion for *emitting* a graviton (the presence of E_1 energy), and thereby being a *source* of gravity, seems to be stricter than the criterion for *absorbing* a graviton (the mere presence of the $\mathbf{d}_0$ component in an object's genome). It might be the case that we need to increase the criteria on the absorber; i.e. we might insist that it has not just a $\mathbf{d}_0$ component in its genome, but that it meet the stricter requirement of having E_1 energy, as defined earlier. This stricter requirement would not only prevent virtual particles (born out of quantum vacuum energy) from being *emitters* of gravitons (and thus sources of gravity), but would also prevent them from being *absorbers* of gravitons --- with the result that virtual particles would not participate at all in the gravitational interaction.

On the other hand, if we *keep* the looser requirement for absorbing gravitons, then we would have a situation where the virtual particles of quantum fluctuations cannot be a source of gravity, but *can* absorb gravitons --- and thus (given their ubiquity) can be a gravitational *sink*. Could such a gravitational-sink effect be an explanation for the extreme *weakness* of gravity in comparison with the other forces? That is, with virtual particles acting as a gravitational sink, could the tens-of-orders-of-magnitude difference in the energy densities between virtual particles and ordinary particles account for the tens-of-orders-of-magnitude difference in strength between gravity and the other forces? Indeed, we already know about a similar effect of virtual particles: vacuum polarization, which causes an effective reduction in strength of the *electromagnetic interaction*.

4.10 Matter-antimatter asymmetry

In constructing the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$), we have found that the displacement $\mathbf{d}_0$ inputs energy into level 1, and also acts as a portal for inputting energy into subsequent levels. Likewise, the displacement $\mathbf{d}_1$ can produce electric charge at level 2, and also at subsequent levels; and $\mathbf{d}_2$ can produce baryon charge at level 3 and above. For $\mathbf{d}_1$ and $\mathbf{d}_2$, let us now suppose the following, more specific, pattern of electric and baryon charge production:

> At the *first* level for which a given of these displacements ($\mathbf{d}_1$ or $\mathbf{d}_2$) is in effect (i.e. its native level), its associated charge (electric or baryon, respectively) takes on a particular sign, either positive or negative (+/-). At the *second* level for which a given of those displacements is in effect, its associated charge takes on the *opposite* sign that it had at the first level. And, at the third level or above, the net charge is *zero*. Or, in short: The charge associated with a given of these displacements ($\mathbf{d}_1$ or $\mathbf{d}_2$) *alternates* in sign for the first two levels that the displacement is in effect, and is net zero at later levels. Note that this charge-production scheme is *non*conservative at each of the first two steps (but might be conservative overall).

Thus, the electric charge (associated with $\mathbf{d}_1$) that is produced at level 2 has, let us say, *negative* sign; the electric charge produced at level 3 has *positive* sign; and the electric charge produced at level 4 and above has a net value of zero. Likewise, the baryon charge (associated with $\mathbf{d}_2$) that is produced at level 3 has, let us say, positive sign; the baryon charge produced at level 4 has negative sign; and is net zero at level 5 and above.

The result of this pattern of charge production is leptons with negative electric charge at level 2 (which, after decays, yields electrons); baryons with positive electric charge and positive baryon charge at level 3 (which yields protons); and objects at level 4 (let's call them *transbaryons*) that have *zero* electric charge and *negative* baryon charge. The transbaryons at level-4, having zero electric charge, are thus candidates for *dark matter*. These results are shown in Fig. 3.

Levels 1 through 4 in Fig. 3 constitute a world of dark energy and matter --- with a conspicuous absence of antimatter (i.e., matter-antimatter *asymmetry*) --- which comports with the world that we currently observe.

In conclusion, system P's mechanism for constructing the physical universe --- via a sequence of *discrete* displacements, each of which may be nonconservative of charge --- offers a simple way to generate the observed pattern of matter-antimatter asymmetry, while also yielding a new candidate for dark matter.

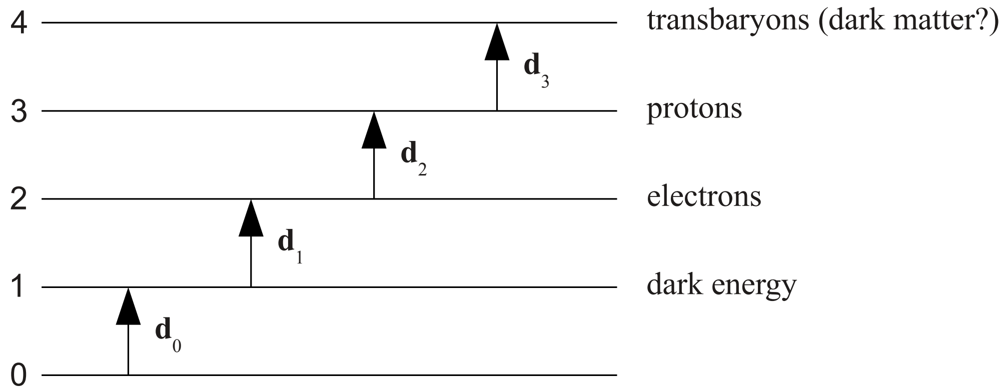

Fig. 3 The spectrum of particle types that the displacement sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$) for system P would yield, given the pattern of alternating-sign-then-zero charge production that we have assumed for the first three steps/levels at which a displacement is operant (excepting $\mathbf{d}_0$). This particle spectrum comports with observed matter-antimatter asymmetry; and level 4 yields a new candidate for dark matter.

4.11 Primary and secondary displacements

In contrast to the charge-production scheme described above, which yields matter-antimatter asymmetry, our present-day experience is that *all* electric- and baryon-charge production is *fully* conservative. Consideration of this, as well as our model of the fundamental interactions developed above, in which some displacements propagate "along the lines of" other, *already-existing* displacements, suggests the existence of two different displacement types. These displacement types will be called *primary* and *secondary* --- defined as follows:

- The *primary displacements* are the ones that *construct* the *infrastructure* of system/world P, the sequence for which we have denoted as ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$). That is, starting at level 0, the primary displacements construct the subsequent levels (1, 2, 3, 4, etc.) and the connections/displacements between them; and relations between these displacements construct the different spaces of the system. In addition, the primary displacements input energy into the levels that they construct, which is partitioned among (and within) the spaces, thereby constructing what may be called the (initial population of) *primary entities/particles* of the system (i.e. dark energy at level 1, leptons at level 2, baryons at level 3, and --- possibly --- transbaryons/dark matter at level 4). In our scheme of matter-antimatter asymmetry, the *primary* displacements $\mathbf{d}_1$ and $\mathbf{d}_2$ (at least) are *nonconservative* of charge in the first two steps at which they are operant. The primary displacements are all *forward* displacements.
- The *secondary displacements* may be forward, backward, or lateral/intralevel. These are the displacements that happen once the infrastructure of the universe has been constructed/established by the sequence of primary displacements.

> Among these secondary displacements are the ones that we have described as being responsible for the fundamental interactions, the processes of which construct --- let us say --- *secondary entities/particles* of the system (i.e. photons, mesons, gluons, gravitons, and W/Z particles). In essence, the secondary displacements utilize the *existing* infrastructure (of levels, and the primary displacements which connect the levels) as a kind of interaction *network* --- moving energy (and information) in all directions (forward, backward, and lateral). In this respect, the levels and primary displacements act as *nodes* and *edges*, respectively, in a *communication network*. The secondary displacements (unlike the primary displacements) are, evidently, *fully conservative* of charge (electric and baryon).

To denote the secondary *forward* displacements, we will utilize the same notation that is used for the primary displacements; i.e. $\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, etc. When using these symbols, either the context or explicit statements will tell us whether they represent the primary or secondary type. Likewise, for the *backward* displacements (which are *always* secondary), we may use the notation $-\mathbf{d}_0$, $-\mathbf{d}_1$, $-\mathbf{d}_2$, etc. (as we have already done above); or we may state it in words, e.g. "the backward displacement of E_j energy onto level j-1" (as we have also done above). And for lateral/intralevel displacements (which, too, are *always* secondary), there is no special notation yet developed --- so we simply state it in words, e.g. "the lateral/intralevel displacement of E_j energy within level j" (as we have done above).

In summary, primary displacements are about *constructing* the infrastructure of a *new* system or world, and priming it with energy; secondary displacements are about what happens within that *already-existing* infrastructure. Both primary and secondary displacements are forms of communication, since they both communicate energy and information among levels. However, the primary displacements only communicate in *one* direction --- *forward*; whereas the secondary displacements may communicate in *all* directions: forward, backward, and lateral. So, to be clear, the primary displacements do not just disappear after their initial creation; rather, they remain operant, and form a system of communication *channels* along which the secondary displacements can propagate.

We said above that the *secondary* displacements include those that are responsible for the fundamental interactions. An example of a secondary displacement that is *not* a fundamental interaction per se would be the creation of an electron-positron pair from a photon --- which can be described as the (conservative) secondary forward displacement of the photon energy, along the line of $\mathbf{d}_1$, from level 1 to level 2. Similarly, the creation of a proton-antiproton pair from a photon can be described as the (conservative) secondary forward displacement of the photon energy, along the sequence ($\mathbf{d}_1$, $\mathbf{d}_2$), from level 1 to level 3.

4.12 Postulates 5 and 6

Recent developments in the model suggest the need for two more postulates:

Postulate 5: Within the infrastructure of "nodes and edges" that is constructed by a sequence of *primary* displacements, *secondary* displacements may be propagated in all directions (backward, forward, and lateral/intralevel).

Postulate 6: A displacement of any type, to a given level, involves the input/communication of energy onto that level, which constitutes an object/entity (e.g. a "particle", real or virtual) at that level.

4.13 Constructing position, velocity, acceleration, and spin properties

As concluded in section 4.4.1, $\mathbf{d}_0$'s independence from ordinary space causes entities such as particles to be located *everywhere in space* --- a phenomenon that is familiar to quantum mechanics. However, it is evident (all around us) that particles can also acquire (more or less) definite positions --- and velocities, and spins --- within ordinary space. We outline below how these properties are constructed in the present model.

4.13.1 Position

We have already described how $\mathbf{d}_0$ "looks" from the perspective of $\mathbf{d}_1$: as an isotropic, homogeneous three-dimensional space (i.e. ordinary space, or S^3_{01}). We now ask, how does $\mathbf{d}_0$ look from the perspective of (an observer at) *level 0*? The answer (by postulate 3) is simply that $\mathbf{d}_0$ *is a one-dimensional vector*. Furthermore, by the scope rule, this interpretation/meaning of $\mathbf{d}_0$ (from the perspective of level 0) is available/operant *everywhere* within system/world P (whereas the *three*-dimensional meaning from the perspective of $\mathbf{d}_1$ is only operant at level 2 and above, since $\mathbf{d}_1$ itself is only operant at those levels).

Consider now an observing object/particle *A* at *level 2* or above (e.g. an electron or proton), which thus has, at minimum, $\mathbf{d}_0$ and $\mathbf{d}_1$ in its sequence/genome. Consider also an observed object *B* at *level 1* or above (e.g. a photon, electron, proton); i.e. an object that has, at minimum, $\mathbf{d}_0$ in its genome. In general, *A*'s $\mathbf{d}_1$ component sees $\mathbf{d}_0$ as ordinary, isotropic, homogeneous three-dimensional space; and, specifically, it sees *B*'s $\mathbf{d}_0$ component (and therefore *B* itself, as per section 4.4.1) as being smeared throughout this space --- and thus, in this sense, having every possible position within ordinary space, but no particular position. In other words, from the perspective of *A*'s $\mathbf{d}_1$ component, object *B* *fills all of space*.

By the scope rule, however, the meaning of *B*'s $\mathbf{d}_0$ component from the perspective of *level 0* is also available to object *A*; to wit, from this perspective, *A* sees *B*'s $\mathbf{d}_0$ component as a *one-dimensional vector*. We interpret that this meaning of $\mathbf{d}_0$ is just the *position vector* of *B* with respect to *A*; that is, the position vector of *B* **relative to** *A*.

Since *A* is *any* object at level 2 or above, then *every* object at level 2 or above generates a relative position vector for *B* in the same way. And since *B* is *any* object at level 1 or above, then relative position vectors are generated in this way for *every* object at level 1 or above. In general, a relative position vector so constructed may be denoted by the symbol $\mathbf{r}_{d0}$, where the "d0" in the subscript indicates that this construction depends on the presence of the displacement $\mathbf{d}_0$ in the genome of object *B*. In the language of Zurek et al., we might also call $\mathbf{r}_{d0}$ the *fundamental* position **pointer** for object *B*, with respect to *A*. Moreover, if observing objects such as *A* constitute the "environment", then some combination of all the $\mathbf{r}_{d0}$'s/pointers so constructed might yield the "pointer basis" [14], [15], [16].

Since $\mathbf{r}_{d0}$ is the position vector of *B* **relative to** *A*, then different objects/observers *A* at level 2 or above will construct different relative position vectors for *B*, with (generally) *different* magnitudes (*distances*). In other words, these observers will validly *disagree* about the distance to *B*.

Given that the construction of a *relative* position vector for an object depends on that object having a $\mathbf{d}_0$ component in its sequence/genome, then, for an object/entity that *lacks* a $\mathbf{d}_0$ component (i.e. an entity at level 0), the construction of a relative position vector cannot occur, and so the position of such an object will presumably be *absolute*, not relative (i.e., all observers *A* will *agree* on the distance to *B*). This result is supported by the following analysis, which stems from asking the question: From the perspective of an observer at level 2 (or above), what is the "position" of an object/entity at level 0?

Let us use the symbol $\mathbf{r}_{L0}$ to refer to the hypothetical position vector for an object at level 0. To sort out the nature of $\mathbf{r}_{L0}$ we note that, due to the scope rule, an entity at level 0 is operant *throughout* world P; which implies that the "position" of such an object is *everywhere* within the ordinary space of world P --- and so the "distance" to that object is effectively *zero*. That is, *all* observers at level 2 or above will *agree* that the distance to an object/entity at level 0 is exactly *zero*. It follows that the *magnitude/length* of $\mathbf{r}_{L0}$ (being zero from the perspective of *all* observers at level 2 or above) is *not* relative --- rather, it is *absolute*.

In summary, from the perspective of an observer at level 2 or above, an object at level 1 or above (i.e. an object that possesses a $\mathbf{d}_0$ component in its sequence/genome) has a *relative* position vector, whose magnitude (distance) is typically *different* for each observer --- and so that distance is a *relative* quantity. In contrast, every object/observer at level 2 or above agrees that the distance to an entity at level 0 (which *lacks* a $\mathbf{d}_0$ component in its genome) is *zero* --- and so that distance is an *absolute* quantity. In other words, *relative* distance is only supported for objects *at level 1 or above* (where $\mathbf{d}_0$ is operant); *below* level 1 (where $\mathbf{d}_0$ is *not* operant), distance is *absolute*.

4.13.2 Spin

In the above analysis, the relative position vector (i.e. the position vector of *B* with respect to *A*) is constructed when *A* refers to the (perspective of the) observer at level 0 to interpret the meaning of *B*'s $\mathbf{d}_0$ component.

Likewise, object *B* can (without help from *A*) refer to the observer at level 0 to interpret the meaning of its *own* $\mathbf{d}_0$ component. The result, again, is that $\mathbf{d}_0$ is a one-dimensional vector. However, since this interpretation of $\mathbf{d}_0$ (as a one-dimensional vector) is *not* relative to another object (*A*) within world P, then it will yield a property that appears to be *intrinsic* to *B*. To wit, it should yield an intrinsic or internal axis (and orientation) for object B. Since B is *any* object at level 1 or above, then *every* object at level 1 or above will have such an internal axis. We interpret this internal axis to be the property known as *spin*.

Why, according to the present model, some objects/particles have half-integral spin (i.e. fermions) and others have integral spin (i.e. bosons) is not yet clear, but the following is likely to be an important clue: In the present model, the primary creation of fermions occurs via *forward* displacement, whereas the creation of bosons occurs via *non*-forward displacement.

4.13.3 Velocity

Let us now move on to the succeeding displacement, $\mathbf{d}_1$, and ask: what is the meaning of that displacement from the perspective of (an observer at) level 0? The answer is that (like $\mathbf{d}_0$) it is a one-dimensional vector, and (due to the scope rule) this meaning of $\mathbf{d}_1$ is available/operant throughout world P.

Now consider two objects, A and B, *both at level 2 or above* (e.g. electrons or protons), which thus have (at minimum) $\mathbf{d}_0$ and $\mathbf{d}_1$ components in their genomes. By the scope rule, the meaning of B's $\mathbf{d}_1$ component from the perspective of *level 0* is available to object A; to wit, from this perspective, A sees B's $\mathbf{d}_1$ component as *a one-dimensional vector*. But what property should be associated with this $\mathbf{d}_1$ vector? Since $\mathbf{d}_1$ is subsequent to $\mathbf{d}_0$, then object A may see $\mathbf{d}_1$ as being logically "attached" to the end of the relative position vector associated with $\mathbf{d}_0$ (i.e. $\mathbf{r}_{d0}$) --- which evokes the image from classical mechanics of the *velocity vector* of an object being attached to the end of its position vector, thereby suggesting that the property of *velocity* might be associated with $\mathbf{d}_1$. This association is further supported by the following argument.

Recall that we earlier associated $\mathbf{d}_0$ with *energy*, and $\mathbf{d}_1$ with *time*, the product of the two being *action*. Since we have just associated $\mathbf{d}_0$ also with the *position* property, then (in order for the product of the properties associated with $\mathbf{d}_0$ and $\mathbf{d}_1$ to be action) $\mathbf{d}_1$ must be associated with *momentum*, and thus with *velocity*.

We therefore interpret that the meaning of B's $\mathbf{d}_1$ component, as seen by A (applying the perspective of level 0), is just the *velocity vector* of B with respect to A; that is, the velocity vector of B **relative to** A --- which may be denoted as $\mathbf{v}_{d1}$, where the "d1" in the subscript indicates that the construction of this vector depends on the presence of the displacement $\mathbf{d}_1$ in the genome of object B. Since A is *any* object at level 2 or above, then *every* such object generates a relative velocity vector ($\mathbf{v}_{d1}$) for B in the same way. And since B is *any* object at level 2 or above (i.e., any object having a $\mathbf{d}_1$ component), then relative velocity vectors/$\mathbf{v}_{d1}$'s are generated in this way for *every* such object.

Due to the *relative* nature of the velocity vectors so constructed, different objects/observers A will construct *different* $\mathbf{v}_{d1}$ velocity vectors for B, with (generally) *different* magnitudes (*speeds*). Thus different observers A may validly *disagree* about the speed of B. Indeed, leptons and baryons (level-2 and level-3 objects, respectively, in the present model; which both therefore have $\mathbf{d}_1$ components) *do* see each other as having relative speed.

On the other hand, given that the construction of a *relative* velocity vector for an object depends on that object having a $\mathbf{d}_1$ component in its genome, then, for an object/entity *B* that *lacks* a $\mathbf{d}_1$ component (i.e. an object at levels 0 or 1), the construction of a relative velocity vector cannot occur, and so all observers *A* (at level 2 or above) will *agree* on the *same* speed for *B*; that is, the speed of *B* will be *absolute*, not relative.

Relative velocity is thus only supported for objects *at level 2 or above* (where $\mathbf{d}_1$ is operant); and, for objects at levels 0 and 1, which lack $\mathbf{d}_1$ in their genome, *there is no relative velocity/speed*. Indeed, the *photon* is a level-1 object in the present model, and is known to have absolute speed (the speed of light, *c*); likewise, the graviton and gluons are level-1 objects, and are believed to have absolute speed, with the same nonzero value as the photon.

Furthermore, dark energy is another level-1 entity in the present model, and so we predict that its speed is also *absolute*; i.e., that all observers (*A*) at level 2 or above will *agree* on the value of its speed. However, in this case that speed is likely to be *zero*.

Why should dark energy have an absolute speed of zero, while other level-1 objects (photon, gluon and graviton) have a *nonzero* absolute speed? To answer this, we must recall that (in the present model) fundamental forces, and thus *accelerations*, are the product of *nonforward* displacements (i.e. backward and lateral/intralevel displacements). But the process of creating dark energy, it may be recalled, involves only the *forward* displacement $\mathbf{d}_0$ --- so there is no possibility in that process of accelerating dark energy to a finite speed; and so its speed is zero.[10] In contrast, it may be recalled that the processes of creating the photon, gluon and graviton (the latter, to be further elaborated in section 4.14) all involve *nonforward* displacements, which yield accelerations, and thus *non*zero speeds.

We can also ask: Why is the speed of light (and gluons, gravitons) a *constant*? Answer: Because nonforward displacements are necessarily involved *only* in the photon's *creation*, not in the aftermath of its creation. If nonforward displacements do somehow become involved in the aftermath, then acceleration can occur and the situation becomes *noninertial*, in which case the speed of the photon may *not* be constant. The same applies to dark energy: its speed remains constant (at zero), as long as nonforward displacements have no involvement in the aftermath of its creation (a situation that might *always* be the case).[11]

In summary:

> The construction of *relative* speed for an object depends on that object having a $\mathbf{d}_1$ component in its genome. Indeed, objects such as the electron and proton, being level-2 and level-3 objects, respectively, *have* a $\mathbf{d}_1$ component in their genomes, and thus have relative speed. The photon, however, being a level-1 object, *lacks* a

10 An alternative derivation of zero speed for dark energy is as follows: Since dark energy is a *single* entity spanning all of ordinary space, and indeed it is the energy of space itself, then it cannot really move *within* that space --- and so its velocity is zero.

11 Incidentally, being a level-1 entity, dark energy is *massless* (as concluded earlier). Since it is massless and has a speed of *zero*, then dark energy is apparently an *exception* to the result from special relativity that *all* massless entities travel at the speed of light.

$\mathbf{d}_1$ component in its genome, and so can only have *absolute* speed.

The photon's speed is *nonzero* because a nonforward displacement is involved in its creation, which yields acceleration during that process. (In contrast, the speed of dark energy, while also absolute, is likely to be zero, because its creation is due solely to the *forward* displacement $\mathbf{d}_0$.)

Once a photon is created with its nonzero speed, only the subsequent involvement of nonforward displacements (and thus forces/accelerations) can *change* that speed; in the absence of those (i.e., if the situation remains *inertial*), the speed of the photon will be a *constant*.

The present model thereby provides a kind of *genetic* explanation for (or *derivation of*) the second postulate of special relativity; that is, we attribute the absoluteness of the speed of light to the *absence* of the $\mathbf{d}_1$ "gene".

Finally, we ask, what is the speed of an object at *level 0*?

Let us use the symbols $\mathbf{v}_0$ and $\mathbf{v}_1$ to refer to the velocity vectors for objects at levels 0 and 1, respectively.

We have already made the case that the speed $|\mathbf{v}_1|$ of a level-1 object is absolute, and that its value is zero if the object was created with *forward* displacement (as for dark energy), but is nonzero if it was created with *nonforward* displacement (as for photons, gluons, and gravitons). We now make the same case for the speed $|\mathbf{v}_0|$ of a *level-0* object/entity.

First we consider a *natural* level-0 object; i.e., an object whose presence at level 0 came about *without* the involvement of nonforward displacement. In section 4.13.1 we found that, due to the scope rule, an object/entity at level 0 is uniformly operant *throughout* world P, which implies that the "position" of such an object is effectively *everywhere* within the ordinary space of world P; i.e. the position of a level-0 object is *all of space*. Since its position is *everywhere* in space, then such an entity does not travel or propagate from one point in space to another --- for, *it is already there*. It follows that *all* observers (at level 2 or above) will *agree* that its speed is zero. The speed of a natural level-0 object/entity is thus absolute, and *zero*.

On the other hand, a *non-natural* level-0 object is one that is created by some process at level 1 or above, and is backward (nonforward) displaced *onto* level 0. Because that creation process occurs at level 1 or above, it has a $\mathbf{d}_0$ component, and thus has a position property within ordinary space relative to observers at level 2 or above. Upon backward displacement onto level 0, however, the object (which originates at a particular position within ordinary space) becomes a *level-0* entity which (due to the scope rule) is *instantly* operant/available *everywhere* in space; so *all* observers at level 2 or above will *agree* that its speed is *infinite* (and thus nonzero). Hence, the speed of a non-natural level-0 object is absolute, and *nonzero*.[12]

12 Note that backward displacement onto level 0 may produce an exception to the following statement from section 2: "nothing that comes into being with the construction of the physical universe exists at level 0".

4.13.4 Acceleration

Now, for the succeeding displacement, $\mathbf{d}_2$, we ask: what is the meaning of that displacement from the perspective of (an observer at) level 0? As usual, from that perspective, $\mathbf{d}_2$ is a one-dimensional vector; and so, following the pattern above, it is suggested that we associate this meaning of $\mathbf{d}_2$ with a relative *acceleration* vector.

Consider now an observer *A* at level 2 or above, and an observed object *B* at level 3 (e.g. a proton). Observer *A*, applying the perspective of level 0, will see *B*'s $\mathbf{d}_2$ component as a *relative* acceleration vector. Apparently, then, *B* can have an acceleration property relative to *A* simply by virtue of having a $\mathbf{d}_2$ component in its genome; and since this property is relative, then different observers *A* may register different *values* for the magnitude of this acceleration.

However, as indicated earlier (e.g. section 4.4.4), the properties associated with an object's $\mathbf{d}_2$ component are *confined* within the *internal* spaces of that object; and so the relative acceleration associated with $\mathbf{d}_2$ is also confined or "hidden" within the interior spaces of objects at level 3 or above, such as the proton. It follows that, *outside* of those internal spaces, i.e. *within the ordinary space of our direct experience*, the relative acceleration associated with $\mathbf{d}_2$ is not supported, and so all acceleration within that realm should be *absolute*, not relative. Indeed, in our direct experience all observers *agree* on the value of an object's physical acceleration (as measured by an accelerometer), and so that acceleration *is* absolute.[13]

As with the position and velocity properties discussed above, for the situation in which the acceleration is always absolute (i.e., within the ordinary space of our direct experience), the magnitude/value of the acceleration can be either zero or nonzero, depending on whether or not nonforward displacements are involved. When they are *not* involved, the acceleration will be *zero*, and will remain a *constant* at that value. When they *are* involved, the acceleration can be *nonzero*, and its value may be a variable. But this result is basically just the law of inertia, or Newton's first law of motion.

4.13.5 Backward displacement onto level 0

In section 4.13.3, we concluded that an object/entity created by backward displacement onto level 0 becomes *instantly* operant/available *everywhere* in space; so, in this sense, its speed is *infinite*. It is proposed, therefore, that backward displacement onto level 0 produces *instantaneous* interaction/communication within the physical universe. Of course, it is just such an interaction that is needed to explain what happens in the quantum "collapse" phenomena, where the values of properties are instantaneously correlated across space --- e.g., in the double-slit experiment, or in EPR/entanglement-type experiments (more on this in section 4.13.6).

13 In contrast, the *position* and *velocity* of an object within the ordinary space of our experience can, as described above, be relative *or* absolute, depending on the presence or absence of the displacements $\mathbf{d}_0$ and $\mathbf{d}_1$, respectively, in its genome. Physical relative *acceleration*, on the other hand, requires the presence of $\mathbf{d}_2$, whose associated properties are confined to the *internal* spaces of an object having that component, and thus does not manifest within the ordinary space of our experience. Consequently, *all* of the physical acceleration in our direct experience is *absolute*.

Just as backward displacement onto *level 1* may be a feature of all energy forms that are native to level 2 or above (i.e. E_2 energy, E_3 energy, etc.), so also backward displacement onto *level 0* may be a feature of all energy forms that are native to *level 1* or above (which is to say, *all* energy forms within world P --- i.e. E_1 energy, E_2 energy, E_3 energy, etc.). In this respect, instantaneous interaction via backward displacement onto level 0 might be a *truly* universal mode of communication, performed by *all* energy types, including quantum vacuum energy (in contrast to gravity, which, as we found, is *not* totally universal, since it *excludes* quantum vacuum energy as a source).

Backward displacement of E_1, E_2, and E_3 energies *onto level 0* may be denoted by $-\mathbf{d}_0$, ($-\mathbf{d}_1$, $-\mathbf{d}_0$), and ($-\mathbf{d}_2$, $-\mathbf{d}_1$, $-\mathbf{d}_0$), respectively.

An interaction via backward displacement onto level 0 may thus be described as follows: Energy associated with object *A* backward displaces onto level 0, producing an object at that level. Due to the scope rule, this object is then universally and instantaneously operant throughout all of ordinary space.

4.13.6 Constructing definite values for properties; classicality and classical precedence

Recall that object *A*'s $\mathbf{d}_1$ component sees object *B*'s $\mathbf{d}_0$ component (and thus *B* itself) as being spread out across ordinary space. But the view of *B*'s $\mathbf{d}_0$ component from the perspective of *level 0* may then be used by *A* to construct a position vector for *B* (relative to *A*). Likewise, the view of $\mathbf{d}_0$ from level 0 also yields the *spin* property of objects, and the view of $\mathbf{d}_1$ from level 0 yields relative velocity/speed. The common denominator here is that the construction of all of these properties require *the perspective/view from level 0*.

Given that level 0 is prior to everything else in the system, then its view of $\mathbf{d}_0$ has greater priority (and *precedence*) than the *subsequent* view of $\mathbf{d}_0$ from the perspective of $\mathbf{d}_1$. Such precedence presumably means that the view of $\mathbf{d}_0$ from level 0 can *override* (over*write*?) the smearing out that occurs from the perspective of $\mathbf{d}_1$, and thus may be used to construct a *definite* position for an object that has a $\mathbf{d}_0$ component. This apparently explains (at least in part) how the position of an object can initially be *all of space*, and then "collapse" down to a definite point in space.

Generalizing this result, the priority of the view of $\mathbf{d}_0$ and $\mathbf{d}_1$ *from level 0* enables construction of a world in which objects can have *definite* position, spin, and speed --- i.e. the *classical* world. That the classical world is rooted in a process that has greater priority/precedence presumably explains why it manifests as more real, robust, and (according to Bohr [16, p.1], [14, p. 2]) fundamental than the fuzzy/smeared-out quantum world. Indeed, we might say that the priority/precedence of the perspective from level 0 yields classicality and *classical precedence*.

Given its precedence, however, if the view from level 0 were *sufficient* to cause collapse by itself, then every object in the universe would likely have a definite position, spin, and speed *by default*. But we know (e.g. from the double-slit and entanglement experiments) that this is not the case. Indeed, if anything, the default is that an object *does not* have definite values of those properties, but *can acquire them via interaction* *with a "measuring" apparatus*. This leads us to conclude that the view from level 0 is *necessary*, but not sufficient, to give an object a definite position, spin, or velocity within ordinary space.

It is easy to see why the view from level 0 would be insufficient to establish definite values for those properties: Ordinary space is only operant *at level 2 and above*, so positions and directions within that space only have meaning at those levels. The observer at *level 0* therefore "knows" nothing (i.e. is agnostic) about particular positions and directions in ordinary space, and thus cannot *by itself* assign meaningful values to them. The process of assigning values to those properties therefore requires the participation/input of an object/observer, *A*, *at level 2 or above*, for which positions and directions within ordinary space *do* have meaning. Such an observer (*A*) constitutes the "measuring" apparatus, in whole or in part.

The construction of position, spin and velocity properties, *and* their values, is thus a *co-creation* process involving the observer at level 0 *and* at least one observer at level 2 or above (i.e. the measuring apparatus). Nevertheless, it is still the priority/precedence of the view from level 0 that enables the "collapse" phenomena to occur, allowing classical definiteness to overwrite (and take precedence over) quantum fuzziness.

As an example of how the process might work, consider two interacting objects *A* and *B* (where *A* is the observing object, at level 2 or above; and *B* is the observed object, at level 1 or above). First, *A*'s $\mathbf{d}_1$ component sees *B*'s $\mathbf{d}_0$ component (and thus *B* itself) as being smeared out across all of space. Second, *A* uses the perspective of level 0 to interpret *B*'s $\mathbf{d}_0$ component as an *indefinite* relative position vector (or pointer --- the *fundamental* pointer for *B* with respect to *A*). Third, the *interaction* between *A* and *B* causes *A* to *construct* information about *B*'s distance, speed, and orientation variables. Fourth, object *A* then uses that information to *assign values* to *B*'s variables, via the following process: *A* passes the constructed information about *B* to (the observer at) level 0, which then writes/records those values --- thereby constructing, e.g., a *definite* position vector for *B* with respect to *A*. Given that the scope of the observer at level 0 is universal and instantaneous, then all other observers (*A*) within world P will instantly *agree* on the results; e.g., that *B* has a certain position within ordinary space.

Note that object *A* (by itself) does *not* have the needed scope to *write/record* a value for *B*'s position variable (or any other of *B*'s variables); rather, *A* must pass the constructed position information to the observer at level 0, which *does* have the scope to write/record values. The position information is likely passed to the observer at level 0 via *backward displacement onto level 0*, which (as described in section 4.13.5) acts instantaneously across all of space, and is able to not only write a "1" (present) at a particular location, but also to write "0" (not present) at all other locations, thereby bringing about "collapse" at all locations except one. Moreover, the time-independence of the observer at level 0 may account for its ability to write values (e.g., in delayed-choice experiments) in defiance of the normal temporal ordering of events as seen from the perspective of observers (like you and me) at level 2 or above.

As another example, consider the construction of definite spins for entangled objects B_1 and B_2 (both of which are at level 1 or above). First, *indefinite* spins are constructed for both B_1 and B_2 when these objects refer to the view of their $\mathbf{d}_0$ components from the perspective of level 0 (as described in section 4.13.2). The spins are indefinite (i.e., not married to any particular direction in space) at this stage because, as described above, the observer at level 0 is unknowing/agnostic about directions within ordinary space. Next, object B_1 interacts with an observing object A (which is at level 2 or above, and constitutes the "measuring" apparatus, in whole or in part). Via this interaction, object A constructs orientation information for B_1, and passes it (via backward displacement) to the observer at level 0, which writes a definite orientation/direction for the spin of B_1 --- say, spin "up". Given the universal scope of the observer at level 0, it also instantaneously writes spin "down" for object B_2, irrespective of the distance between B_1 and B_2.

Clearly, as already alluded to many times, the observer at level 0 does not "see" or respect the space and time relations (or intervals) between objects that seem so important and imposing for observers (like you and me) at level 2 and above. Rather, the observer at level 0 only sees and respects *logical* relations --- and is thus analogous to the CPU of a computer, and/or the kernel of the operating system, neither of which knows anything about the spatiotemporal effects that are generated on the screen by a running program/process, but which nevertheless perform underlying logical operations that are needed to generate those effects. This analogy is expanded in the next subsection.

4.13.7 An analogy from computing

The processes described above, by which objects acquire properties with definite values, might have a ring of familiarity for readers who have some background in computer programming. This is because there is a strong analogy between the two, as follows.

In a compiled programming language such as C++, variables and their types are *declared* first, and then *assigned* values during run time. Thus, suppose B is an object within an application program that is running under the operating system *kernel*. The application program (e.g. a word processor, spreadsheet, web browser, etc.) does not have the scope to write values for B's variables directly to memory; rather, it must initiate a *system call* to the operating system kernel (which *does* have the needed scope) to write those values. The value to be assigned is included in the system call as an *argument*, and it is written/recorded by means of the kernel placing that value in the memory location/cell that was allocated for that B variable during compilation.

Now, in the present model (system/world P), suppose that B is an object at level 1 or above, and that the view of one of B's displacement components (e.g. $\mathbf{d}_0$ or $\mathbf{d}_1$) from the perspective of level 0 merely *declares* a corresponding variable and its type (e.g., relative position, velocity, or spin), without assigning a value to it. The variable is then assigned an actual value via interactions with the "measurement" apparatus that occur during "run time". Specifically, an object A (constituting the measurement apparatus, in whole or in part) can initiate the assignment of values to B's variables, but does not have the necessary scope to actually *write* them. The observer at level 0 (the "kernel"), however, *does* have the necessary scope. Thus, A's assignment of values to B's variables is basically a "system call" to the observer at level 0 to write or record those values/arguments. As previously indicated, the basic mechanism/interaction by which such system calls/assignments are performed is likely *backward displacement onto level 0*, since that interaction acts instantaneously across ordinary space.

4.13.8 The quantum ***construction*** problem

An underlying theme of this paper is that everything constituting the physical universe is *constructed*, including space and time. A century of quantum mechanics (theory and experiment) echoes this same theme: properties and their values (such as position, velocity, spin, etc.) that were thought to be *there* in the system of interest, needing only to be measured, were actually found to be *constructed* --- via unknown mechanisms, but which included *interaction of the system with a "measuring" apparatus*. It follows that "the quantum *measurement* problem" should really be called "the quantum *construction* problem", and perhaps rephrased as: How are properties such as position, velocity, and spin --- and their values --- *constructed*?

Although we have not completely solved the quantum construction problem in this paper, we have (if the model is basically correct) made several advances.

4.14 Revisiting gravity

Recall our earlier result that (the emission phase of) gravity should be attributed to a *nonforward* displacement of E_1 energy --- either backward displacement onto level 0, or lateral/intralevel displacement onto level 1. However, if gravity were attributed to *backward* displacement of E_1 energy onto level 0, then (as concluded in section 4.13.3) the graviton would have a speed of *infinity*. But, of course, gravity actually has a *finite* speed --- indeed, all indications are that it propagates at the speed of light, c [17]. Apparently, then, gravity cannot be the result of backward displacement onto level 0; and so it should be the result of *lateral/intralevel* displacement of E_1 energy onto level 1. This means that the graviton is a *level-1* object, with only a $\mathbf{d}_0$ component, thereby giving it a *relative* position property, but (due to the lack of a $\mathbf{d}_1$ component) an *absolute* speed.

Accordingly, we ascribe the following aspects/properties to the graviton:

- It has only a $\mathbf{d}_0$ displacement, which may be denoted as $\mathbf{d}_{0,g}$. Thus we may denote the genome for the graviton as $\{\mathbf{d}_{0,g}\}$.
- It (i.e. its $\mathbf{d}_{0,g}$ displacement) is *subsequent* to $\mathbf{d}_0$.
- It (i.e. its $\mathbf{d}_{0,g}$ displacement) is *prior to*, and thus *independent of*, $\mathbf{d}_1$ (since it springs from *intralevel* displacement onto level 1 --- *not* backward displacement from level 2 or above, as with the photon and gluon). Note that, even if $\mathbf{d}_1$ and level 2 did not exist, intralevel displacement of E_1 energy onto level 1 (as the graviton/$\{\mathbf{d}_{0,g}\}$) would *still* occur at level 1 (obviously without any help from, or dependence upon, $\mathbf{d}_1$).
- We thus have the following order of priority: $\mathbf{d}_0$, $\mathbf{d}_{0,g}$, $\mathbf{d}_1$.

The first, penultimate, and last bullet points above indicate that, from the perspective of $\mathbf{d}_1$, the graviton's $\mathbf{d}_{0,g}$ displacement will "look" much like the $\mathbf{d}_0$ displacement; i.e. the graviton/$\mathbf{d}_{0,g}$ will manifest to $\mathbf{d}_1$ as a form of $\mathbf{d}_0$, albeit with slightly less priority (as indicated in the last bullet point). And we have already determined that $\mathbf{d}_0$, from the perspective of $\mathbf{d}_1$, manifests as ordinary, three-dimensional space, S^3_{01}. Thus, due to its likeness with $\mathbf{d}_0$, it is proposed that the presence of a $\mathbf{d}_{0,g}$ displacement (i.e. the presence of a graviton) will have a modifying effect on ordinary space. That is, the $\mathbf{d}_1$ displacement will *combine* the inputs of $\mathbf{d}_0$ and (if present) $\mathbf{d}_{0,g}$ to construct a *hybrid* space, to be denoted as $S^3_{01,g}$, which may be considered as just the ordinary S^3_{01} space modified by the presence of the $\mathbf{d}_{0,g}$ displacement (i.e. the graviton).

In what way does the presence of the graviton/$\mathbf{d}_{0,g}$ modify the ordinary S^3_{01} space? Recall from section 3.4 that the basic construction of ordinary space leaves $\mathbf{d}_0$ and $\mathbf{d}_1$ without position, orientation, and direction properties within that space, which thereby leaves no way (in that process) to establish any special/preferred position or direction --- with the result that (as constructed) ordinary space is perfectly isotropic and homogeneous. In contrast, a graviton/$\mathbf{d}_{0,g}$ *does* have position, direction, and orientation within ordinary space: its *initial* position is the same as the position of the object (e.g. photon, lepton or baryon) that emits it; upon emission, the graviton travels in some direction within ordinary space; and it also has spin. So, from the perspective of $\mathbf{d}_1$, the graviton/$\mathbf{d}_{0,g}$ is a form of $\mathbf{d}_0$ that *has* position, direction and orientation within ordinary space, and thus *does* establish a special position, direction, and orientation; that is, the presence of a graviton/$\mathbf{d}_{0,g}$ has the effect of modifying space: changing it from isotropic and homogeneous S^3_{01} into *an*isotropic and *in*homogeneous $S^3_{01,g}$. Moreover, recall that the $\mathbf{d}_1$ displacement, as seen from the perspective of $\mathbf{d}_0$, yields ordinary/classical *time* (i.e. S^1_{10} ; section 3.5). Since the $\mathbf{d}_{0,g}$ displacement of the graviton will have its *own* perspective of $\mathbf{d}_1$, then it is proposed that the combination of this perspective with that of $\mathbf{d}_0$ will produce a time, $S^1_{10,g}$, that is *different* from S^1_{10}.

The present model may thereby supplement general relativity by explaining, from first principles, the underlying mechanism by which the presence of energy (actually, only E_1 energy) affects the properties of space and time.

4.14.1 Example of a gravitational interaction

The results above allow the following description of a gravitational interaction (which may be taken as an update of, or alternative to, the one given in section 4.9.4).

Consider an observer *A* at level 2 or above, i.e. an observer for which the displacements $\mathbf{d}_0$ and $\mathbf{d}_1$ are operant. As usual, $\mathbf{d}_1$ sees $\mathbf{d}_0$ as ordinary, isotropic, homogeneous, three-dimensional space, S^3_{01}. Consider also an object/particle *B* at level 1 or above, having E_1 energy, which emits a graviton in the direction of *A*. When this graviton arrives at *A*, it will be processed as follows: from the perspective of $\mathbf{d}_1$, *A* will combine the $\mathbf{d}_0$ displacement with the graviton's $\mathbf{d}_{0,g}$ displacement to construct a resultant, *hybrid* three-dimensional space $S^3_{01,g}$. In contrast to S^3_{01}, the directional/positional aspects of the graviton's $\mathbf{d}_{0,g}$ displacement within ordinary space will cause the resultant $S^3_{01,g}$ space to be anisotropic and inhomogeneous. In addition, *A* will combine the views of $\mathbf{d}_1$

from the perspectives of both $\mathbf{d}_0$ and $\mathbf{d}_{0,g}$, thereby transforming from the ordinary time S^1_{10} to the *altered* time $S^1_{10,g}$. In other words, the presence of the graviton emitted by *B* will alter the "geometry" of space-time as seen by *A*.

5 The physical universe is a meaning circuit

The construction of meaning in system P seems to always involve some application of the postulates, including (as derived from postulate 4) the scope, nesting, and inheritance rules. Recall, for example, that $\mathbf{d}_1$ constructs the meaning "$\mathbf{d}_0$ is a three-dimensional space" by first applying postulate 3, which says that "$\mathbf{d}_0$ is a one-dimensional vector", and then applying postulate 4, which says that "$\mathbf{d}_0$ is independent of $\mathbf{d}_1$". Moreover, it was shown that the isotropy and homogeneity of that same space are properties/meanings that come from the application of postulate 4. To delve deeper into the semantic process for system P we therefore ask: where do the postulates themselves come from?

Given their overarching scope in the construction of world P, the postulates must be *prior* to the sequence of displacements ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$), and so must be present/operant at level 0 itself. The postulates thus come into system/world P *via level 0*.

So, application of the postulates to construct meaning amounts to an indirect *referral to level 0* for that purpose. And recall that the position, velocity, and spin properties of objects (*and* their values) are meanings that are constructed via *direct* referral to (the perspective of) level 0, or the observer at level 0. For the construction of meaning in system/world P, therefore, all roads apparently lead to level 0.

We can thus summarize the basic construction process for system P as follows:

a) The displacement sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$) springs *from* level 0.

b) Each entity/object/observer constructed by that sequence then *refers back* to level 0 (either directly, or indirectly via the postulates) to construct meaning.

System/world P (the physical universe) thereby constitutes a *meaning circuit* (similar to the one proposed by John Archibald Wheeler [18]), which *begins* at level 0 and then, within the system --- via the meaning-producing operations of each entity/observer constructed by the sequence ($\mathbf{d}_0$, $\mathbf{d}_1$, $\mathbf{d}_2$, $\mathbf{d}_3$) --- *loops back* to level 0.

Clearly, then, there are *many* "observers" in the system-P meaning circuit: every object/particle/entity, and each of its component displacements, is an observer that plays a role in constructing world P, and is thereby *in the loop* of its meaning circuit. But the *central* role (or linchpin, if you will) in this meaning circuit is played by *level 0*, or the observer at level 0, since every *subsequent* entity in the system has in common that it refers back to that level to construct meaning.

Since level 0 is also the *origin and boundary* of system P (section 2.1), then the act of referring to level 0 (directly or indirectly) may be tantamount to applying/invoking *initial* and *boundary conditions* on the system to construct meaning.

6 The construction of the physical universe is a type of logical derivation

Consider a derivation in the logical system known as *natural deduction* (ND)[14], containing a sequence of *nested* hypotheses. The derivation begins with a state that may be called *level 0*, at which the inference rules (i.e. postulates/axioms) of the system are operant and a set of zero or more initial propositions/assumptions/*premises* are stated. The first hypothesis of the derivation then generates level 1; the second hypothesis generates level 2; and so on. A proposition at a given level can be asserted at (i.e. has within its scope) *all* subsequent levels. So, the postulates/axioms and initial premises (if any) can be asserted at level 1 and above; a proposition at level 1 can be asserted at level 2 and above; and so on. In this way, subsequent levels *inherit* everything from, and *are nested within the scope of*, prior levels. The scopes of these levels can thus be pictured as a Russian-doll-like set of concentric spheres, with each successive scope embedded/contained within the scopes of its priors. Thus the scope, inheritance, and nesting rules that are properties of system P are also properties of system ND. Moreover, a forward *displacement* in system P corresponds to *hypothesis introduction* in ND; and a *backward* displacement in system P may correspond to *hypothesis discharge* in ND. In other words, systems P and ND have many similarities in structure and function, which suggests that: *the construction process for world P (i.e. the physical universe) is a type of logical derivation*.

This result seems to echo John Archibald Wheeler's intuition about "the basic operating principle of the universe", i.e. the "pregeometry":

> What else can pregeometry be ... than the calculus of propositions? [19, pp. 1208-9]

7 Making sense of the displacement types

A displacement type in system P can be designated by selecting *one* term from each of the following two groups of displacement characteristics (with some restrictions, noted below):

1. Primary; secondary.
2. Forward; backward; lateral/intralevel. (Called the *direction*.)

Thus, the designation of a specific displacement type is given by a *doublet* of these terms, such as: primary-forward (which is the type that constructs the infrastructure of world P); or secondary-backward (which is the type that the present model holds to be responsible for the *emission* processes in the strong and electromagnetic interactions, and the emission process of instantaneous interactions in the quantum construction phenomena); or secondary-forward (which is the type that is responsible for the *absorption* processes

14 *Natural deduction* is (since the 1950s) the type of logic most often taught in introductory logic books, where the modifier "natural" is said to indicate that it follows the method/pattern/paradigm by which our minds perform deductive reasoning [20, pp. 2-3], [21], [22].

in the same interactions); or secondary-lateral, which is the type that is responsible for both emission *and* absorption in the weak and gravitational interactions.

Note, however, that the type designation "primary-forward" is actually redundant, since, as stated earlier, all primary displacements *are* forward (i.e. there is no such thing as a *backward* primary displacement); so this designation can be stated equivalently as "primary". Likewise, all backward displacements are necessarily *secondary* displacements (since backward displacements *do not* create new infrastructure of edges/lines and nodes; rather, they propagate along *existing* lines, and onto *existing* levels/nodes); so, for example, the designation "secondary-backward" is equivalent to "backward". And all lateral displacements are secondary; so, for example, the designation "secondary-lateral" is equivalent to "lateral". Lastly, we may omit the hyphens when writing these designations, and change the order of their components.

8 Conclusion

From six very simple postulates, we have managed to provide basic explanations for many hitherto unexplained physical phenomena: the (3+1)-dimensionality of space and time; inflation (its beginning and ending); the quantum of action; dark energy; the small value of the cosmological constant; quark confinement; the construction of position, velocity, and spin properties; etc. In addition, as quantum physics seems to demand, the model elevates observation and observers to key roles in constructing the world, and provides a mechanism for instantaneous communication/influence across all of space, by which the values of particle properties may be correlated, coordinated, and regulated.

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