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A PARADIGM FOR DISCRETE PHYSICS?*

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For close to a century quantum mechanics has been trying to tell us that events are discrete, indivisible and non-local. Yet few attempts have been made to *start* with this basic insight and then reconstruct physics. We outline here an example – perhaps even a paradigm – for constructing such a discrete physics.

We start by postulating finiteness, discreteness, finite computability, absolute nonuniqueness (*i.e.*, homogeneity in the absence of specific cause) and additivity.[1] So far as we can see, any measurable world satisfying these postulates is restricted to three dimensions. Here "dimensions" refer to the cardinal number of independent generators of *ordered* [our postulates allow us to construct the usual ordinal sequence of natural numbers by recursion] sequences of symbols. It is necessary to have two or more distinct symbols [*e.g.*, 0 and 1] and two suffice. Tagging these sequences by $a, b, c, \ldots$ and representing them by *bit strings* $S^a = (\ldots, b_i^a, \ldots)_n$, $b_i \in 0, 1$, $i \in 1, 2, \ldots, n$ we can *synchronize* these strings by using the *universal* ordering parameter n; for example, we can look along all the strings $a, b, c, \ldots$ until we find some n such that for a finite sequence of length s $b^a_{n+i} = b^b_{n+i} = b^c_{n+i} = \ldots$, $i \in 1, 2, \ldots, s$. Such a synchronization will always occur with finite probability. However, as Feller has pointed out,[2] repeated possibilities for homogeneous synchronization is limited by the number of independent sequence generators (which we have shown can be identified as the number of dimensions) available. The case he examines is the probability that the accumulated number of 1's ($k^a = \Sigma_{i=1}^n b_i^a$) is the same for all sequences after n symbols have been generated. Clearly, if r is the number of dimensions, this probability is

$$u_n = \frac{1}{2^{nr}}\left[\binom{n}{0}^r + \binom{n}{1}^r + \ldots + \binom{n}{n}^r\right] \sim \frac{1}{\sqrt{r}}\left[\frac{2}{\pi n}\right]^{\frac{1}{2}(r-1)}$$

It follows that if we use these ordered recurrences as a finite metric, for any finite number of them we can construct a "space" of two or three dimensions which is both homogeneous and isotropic, but that for four or more dimensions, the probability of synchronization across all dimensions becomes vanishingly small for large recurrences. As one of us (DMcG) has pointed out, the theorem is more general than this specific instance. For instance, we can talk of recurrences of a sequence of any finite length of any finite number of symbols synchronized across dimensions, and the theorem still holds.

We now define a distance function in this space. We first define an *ensemble* which, under our postulates, must have finite cardinality but differs from a finite *set* in that it need not necessarily be completely ordered, — or orderable. In this respect our ensemble is what Parker-Rhodes would call a *sort*.[5] Such ensembles will have *attributes* resulting from how they are generated and/or examined, eg. permutations with respect to a reference ensemble and an ordering operator which generates permutations or a specific sub-ensemble with respect to the sub-ensemble and the identity ordering operator. Call the specific generation of an attribute a *state*. Then we define *attribute distance* as the measure dependent solely on the number of states between two ensembles distinguishable by a specific attribute, normalized by the total number of states possible. This is similar to the statistical (in the frequency theory of probability sense) distance defined by Wootters[6] as the "maximum number [N] of distinguishable orientations between" two measured attribute values divided by the square root of N. Clearly zero distance implies indistinguishability from an information-theoretic point of view.

Given any discrete space constructed consistent with our postulates, we require that there exist a total ordering operator T (such as that produced by the Program Universe ordering operator TICK).[4] The universal ordering operator T on which the generations of this ordering operator are based provides a local total ordering for the evolution of each ensemble.

We now define the *increment size* I of an ensemble as the number of generations of some ordering operator t needed to describe (establish local isomorphism with) the increases in attribute distance between an ensemble and some reference ensemble. Similarly we define the *decrement size* D of an ensemble as the number of generations of the ordering operator t needed to describe the decreases in attribute distance between an ensemble and the same reference ensemble. The *total size* $I + D$ of an ensemble is defined as the arithmetic sum of I and D. *Attribute velocity* v is defined as the mathematical rate of change in attribute distance of an ensemble with respect to the ordering operator t; hence $v = (I - D)/(I + D)$. Clearly for any specific attribute and ordering operator v is bounded, defining a *limiting velocity*. It is now straightforward[1], although a bit tedious when due attention is paid to rigor, to show that these definitions allow us to derive the usual "relativistic" composition law for velocities and the "relativistic doppler shift" for the rational fractions provided as velocities by this discrete definition of velocity. The usual Lorentz transformations in 3+1 space follow, adding minimal postulates about "analyticity"; fortunately our discrete physics can be developed in "momentum space"[4] requiring only the rational fractions for comparison with experiment. Indeed, if one sticks to the discrete statistical space and asks for the connection between the "coordinate systems" referred to different reference ensembles in terms of the standard deviation of the velocities, one is able to provide a rigorous derivation of the "Lorentz transformation" between biased random walks pioneered by Stein.[7] Further, consistent examination of the effect of the finite ordering of generation in this discrete space allows one to derive commutation relations which vanish between commensurate attributes and generate the conventional commutation relations between "d-momentum", "d-position" and the components of "d-angular momentum" which lie at the heart of quantum mechanics. This derivation includes, of course, the introduction of complex numbers.

To take this mathematical structure over into a basis for discrete physics, we must relate these numerical results to measurement of mass, length and time (or three dimensionally independent combinations of them) referred to laboratory standards. We have seen that the construction provides us with a "limiting velocity" for *any* attribute, but no guarantee that these will be the same for different attributes. Since we know from experiment that any measurement can be affected, directly or indirectly, by electromagnetism, we conclude that this phenomenon must refer to *all* physical attributes, and hence that (since it requires the most information to establish), the *smallest* of the attribute limiting velocities is to be identified with the limiting velocity c of physics. Since that implies the existence of "supraluminal" velocities which cannot be used for signaling (information transfer) but which can provide *synchronization* or *supraluminal correlation* we claim to have provided a simple way to have a rational understanding of Aspect's and other EPR-Bohm type distant correlation experiments. In the work we summarize below[6], Planck's constant was introduced by identifying the step length in Stein's random walk with the deBroglie phase wavelength hc/E. Now that we can get it directly from the angular momentum commutation relations, we must prove consistency with the other approach, — a task in which we are now engaged[1]. But the unit of mass is left undefined by the topological considerations we have presented so far, and the specific metric generator has been left unspecified. To establish the unit of mass we use the *combinatorial hierarchy*[8] and generate both it and the states by means of *Program Universe*[5].

For a more detailed discussion of earlier work we refer the reader to the extended version[9] of our report to the 7^{th} Congress in this series, and for subsequent progress to Ref.6. The discrete modeling of "events" pioneered by Amson, Bastin, Kilmister and Parker-Rhodes[8] was based on the discrimination operation $S^a \oplus S^b = (..., b_i^a +_2 b_i^b, ...)_n = (..., (b_i^a - b_i^b)^2, ...)_n$, the observation that j linearly independent strings support $2^j - 1$ subsets which *close* under discrimination (*e.g.*, $\{a\}, \{b\}, \{c\}$, $\{a, b, a+b\}$, $\{b, c, b+c\}$, $\{c, a, c+a\}$, $\{a, b, c, a+b, b+c, c+a, a+b+c\}$ where we have used "+" for discrimination and a+a =0, *etc.*,) and the mapping of such sets (starting with 2 basis strings) to generate the unique 4-level combinatorial hierarchy with cumulative cardinals $3, 10, 137, 2^{127} + 136 \simeq 1.7 \times 10^{38}$ terminating at the fourth level. The connection between 137 and $\hbar c/e^2$ and between 1.7×10^{38} and $\hbar c/Gm_p^2 = (m_{Planck}/m_{Proton})^2$ is numerically obvious; in order to justify the identification, these numbers must occur in a dynamics where they represent inverse probabilities for scattering calculated as one case out of the appropriate number of states that have equal prior probabilities. We now claim to have provided this dynamics[6].

The approach presented at the 7^{th} Congress was to construct a growing universe of bit strings by a computer algorithm called *Program Universe* in such a way that the first N_L bits in any string close in some representation of the combinatorial hierarchy and thereafter provide tags (in the sense defined above) or as we call them in this context *labels* for growing ensembles of *address strings*. The algorithm takes two strings, discriminates them and adjoins the result to the universe if it is *not* already there; if it *is*, the program TICKs, *i.e.*, it concatenates an arbitrary bit arbitrarily chosen for each string at the growing end. We have proved that this does indeed automatically generate some representation of the combinatorial hierarchy in the labels. Once the labels close, they have an invariant significance so long as the program runs. Hence we can assume that each is associated with a parameter that we will call mass, which it then becomes the task of the theory to compute in its ratio to the proton (or Planck) mass.

Now that we have tagged ensembles of the type discussed in the first part of this abstract, we see that for each address there is an attribute velocity which, referred to the most probable address string (which has a equal number of zeros and ones), is bounded by ± 1. The discussion in this abstract now justifies our previous identification of the parameter $\beta^o = \frac{2k^*}{n} - 1$ with velocity of a mass state measured relative to the limiting velocity in a frame at rest with respect to the cosmic background radiation. Further, thanks to the Feller theorem, we see that any three strings which have the same velocity can scatter conserving 3-momentum. We therefore extend our previous definition of "event" to include all such scatterings which occur at each TICK. One major advance since the 7^{th} Congress is the derivation of the "propagator" in this scattering theory by a simple probability calculation in the bit string universe. This allows us to put these events together as scattering amplitudes with a pole at the mass of the intermediate particle and use them as the driving terms for a finite particle number relativistic scattering theory. Connection with laboratory space and time is then provided, as before, by our basic epistemological postulate called the *counter paradigm*:

Any elementary event, *under circumstances which it is the task of the experimental physicist to investigate, can lead to the firing of a counter.*

Then the connection between the steps in the random walks and the deBroglie phase and group wavelengths go through as before, and our contact with experiment is as firm as that of any S-matrix theory.

Another advance made recently is a firm identification of the labels which occur in the first three levels of the combinatorial hierarchy with the quantum numbers of the standard model for quarks and leptons. Level one gives us a two-component *chiral* neutrino, level two electrons, positrons transverse gamma rays and the coulomb interaction, while level three can be identified with two flavors of quarks and the associated gluons in a color octet; the color singlet states correspond to neutron, proton, their antiparticles, and the appropriate charge and angular momentum states of the π, ρ, and ω. Weak-electromagnetic unification, and the higher generations will have to come in at level four, if we are on the right track. The structures are there, all right, and the coupling to the first generation will be weak because of the combinatorial explosion which occurs at level four ($2^{127} - 1$ quantum states). We are now faced with the formidable computational task of computing QED, low energy hadron physics, QCD and getting everything right, or close enough so that we can estimate where the approximations are not good enough.

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