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A BIT STRING MODEL FOR MICROPHYSICS*

H. PIERRE NOYES
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

ABSTRACT

We show that a bit string notation containing quantum number labels, and addresses which define velocities, is adequate for describing finite particle number scattering. We derive the strings themselves from a simple computer algorithm starting from the empty string and obtain: relativistic quantum wave mechanics as a continuum *approximation*, the quantum numbers for leptons and hadrons and the scale constants of physics from the combiniatorial hierarchy, and m_p/m_e from the Parker-Rhodes calculation.

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We take as our underlying model for microphysics an evolving universe $\mathcal{U}(N, SU)$ of *bit strings* $S_i = (..., x_i, ...)_N$, $x_i \in 0, 1$ containing $SU + 1$ strings of N bits which grows by discrete steps, or TICKs, obtained by adding a random bit $R \in 0, 1$ with equal probability separately to each string at the growing end; TICK is defined by $\mathcal{U}(N + 1, SU) := \mathcal{U}(N, SU) \parallel R$. Novel strings are generated by *discrimination* $D_N S_i S_j = (..., x_i +_2 x_j, ...)_N$ where S_i and S_j are picked at random from $\mathcal{U}$ and by *complementation* $\neg S_i = D_N S_i I_N = (..., x_i +_2 1, ...)_N$, where I_N is the *anti-null* string containing N 1's; these two operations occur *between* TICKs. We organize the information content of our universe into ensembles labeled by the *combinatorial hierarchy*[1−2] using the first 256 bits of the string as the *label*; the (many in an evolved universe) strings of length $B = N - 256$ in each labeled ensemble are called the *addresses*. For each address string with N^1 1's and N^0 0's (hence $B = N^1 + N^0$) we define a *velocity* $v = (N^1 - N^0)/B$; the average over an ensemble also defines a velocity $v = < N^1 - N^0 > /B$. Whenever, *between* TICKs, all five strings $S_1, S_2, S_3, \neg S_1, \neg S_2$ connected by $D_N S_1 S_2 = S_3 = D_N \neg S_1 \neg S_2$ are already contained in $\mathcal{U}$, *and* $v_3 = 0$, we say that an *event* has occured. From this digital basis we will construct below both macroscopic special relativistic particle kinematics and relativistic quantum wave scattering theory as continuum *approximations*. Because our events occur *between* TICKs the "position" where they occur can never be shrunk to a point; this allows us to identify our events with the unique and indivisible events of quantum theory. Yet, as we will see, they also meet the requirements of special relativity when this theory is interpreted as a macroscopic theory in which events occur in finite space time volumes. We therefore claim that our concept of event *unifies* special relativity and quantum mechanics by means of an underlying digital model.

Before articulating the complete scheme, we illustrate the connection between our notation and Feynman diagrams. Using only the first two bits as a label and an address string as either I_B with $v = +1$ or the null string $O_B = \neg I_B$ with $v = -1$ (which we will obviously later have to justify calling the limiting velocity in dimensional units $\pm c$), we have two basis states $(10)I_B, (01)I_B$, and by discrimination $(11)O_B$. We interpret the two basis labels as a representation of a dichotomous quantum number, a single entry designating a specific quantum number for a *particle* and its complement for the *antiparticle*; since $\neg(10) = (01)$ in this simple environment $\neg$ applied to a *label* is "charge conjugation" C. Applied to the *address* this operation reverses the velocity. Since "time" has to be constructed from an ordered *sequence* of TICKs, this operation has to be interpreted as P rather than as T. Since the quantum number does not reverse, this quantum number can represent a pseudovector which we identify with helicity 1/2. Then the two particles have opposite helicity and the label (11) is a boson with zero helicity component in the single direction we are now considering; *it* has no "antiparticle". Thus our first level is the starting point for a two component neutrino theory with $\nu_L = (10), \bar{\nu}_R = (01)$ and $Z_0^0 = (11)$. The three types of vertices are illustrated in Figure 1a, and the three types of events in Figure 1b. If all legs are interpreted as incoming or all outgoing, a little thought should convince the reader that these are elementary Feynman diagrams to which the usual rules apply.

Once we have supplied the space, time and momentum space background, these diagrams provide the input needed for a minimal unitary relativistic scattering theory developed elsewhere[3] . The additional postulates needed to make this into a dynamics for the system at hand are that particle and quantum can "bind" *kinematically* to form a system with the same mass and *external* quantum numbers as the particle,[4] that the particle and antiparticle "bind" to form the quantum, and that a second quantum can "bind" to the particle-quantum system again without changing the mass or quantum numbers. This leads to the four driving terms given in Figure 1c and Figure 1d. Supplied with the correct coefficients to guarantee two particle unitarity, these then can be used in relativistic Faddeev equations which in the two body sector have, kinematically, the usual Feynman amplitudes as driving terms, but lead to unitary "three particle" amplitudes when the equations are solved.

Since we now know in outline how we intend to construct a dynamical theory, our next step is to see how we enrich the available quantum number spectrum while preserving the information content of the first level; we turn to the combinatorial hierarchy[1,2]. We define a *discriminately closed subset*, or DCsS, as (a) a single non-null string or (b) any set of strings which when combined by discrimination yield another member of the set. Thus for level 1 we have the three DCsS's $\{(10)\}, \{(01)\}, \{(10), (01), (11)\}$. To preserve this information we introduce binary multiplication and look for *mapping matrices* such that (a) they are non-singular so as not to map onto zero, (b) have a DCsS as their unique eigenvectors and (c) are linearly independent. For level

1 these are easily found. Writing the 2×2 matrices as strings according to the rule $(ACBD)(xy) = (Ax + By, Cx + Dy)$ they are $a = (1110), b = (1101)$ and $c = (1100)$ respectively. From these we can form the $2^3 - 1 = 7$ DCsS's $\{a\}, \{b\}, \{c\}, \{a, b, a + b\}, \{b, c, b + c\}, \{c, a, c + a\}, \{a, b, c, a + b, b + c, c + a, a + b + c\}$. Recalling that (with $+$ for discrimination) $a + a = 0$, we see that all seven sets are *closed* under discrimination, and that given n linearly independent ordered strings we can always form $2^n - 1$ discriminately closed subsets, – the number of ways n distinct things can be chosen 1,2,..,n at a time. Thus at level 2 there are seven strings which are "inside" the hierarchy which we symbolize by $i_k, k \in 1, ..7$ and the remaining 8 non-null strings (out of the 15 possible) "outside" the hierarchy symbolized by $o_k, k \in 8, ..15$. The theory contains only three types of vertices (for the quantum numbers) $i_k + i_l = i_m$, $i_k + o_l = o_m$ and $o_k + o_l = i_m$.

We now interpret the four slots as refering to the helicity states of electrons and positrons according to the scheme given in Table I. We see that we now have the correct quantum number content and connections for lowest order QED, and can go on to a full lowest order dynamics once we supply the appropriate momentum factors and interpretation. We believe it possible to develop from this starting point and the minimal unitary scattering theory[3,4] (extended to Faddeev-Yakubovsky equations)[5] a finite particle number version of QED; results will be presented elsewhere[6] . Further, by combining levels 1 and 2 we have the basic six fermions $(\nu_L, \bar{\nu}_R, e_L^-, e_L^+, e_R^-, e_R^+)$ for Weinberg's[7] weak-electromagnetic unification, as well as the basic lowest order diagrams once we invoke the minimal unitary scattering theory; our explanation of mass differs from his. We hope that we have now provided sufficient motivation for the reader to follow our construction of the whole scheme from basic principles.

Our algorithm for creating a universe[8] of bit strings starting from the empty string[4] is displayed in Figure 2. The operator called R picks randomly between the two bit symbols 0 and 1 with equal probability. From it we can also construct the operator PICK which picks any one of the $SU + 1$ bit strings of length N from the current universe $\mathcal{U}(N, SU)$ at random. The operator TICK simply increases the growing end of each string in $\mathcal{U}$ by one random bit and changes N to $N + 1$ any time one of the two operations discussed below fails to produce novelty.

Since our aim is to construct an ever growing universe of distinct symbols, we need to have a way of checking whether or not any symbol we turn up already is in this universe or not. Symbolizing a string S_i by $S_i = (..., x_i, ...)_N, x_i \in 0, 1$, the discrimination operation defined by $D_N S_i S_j = (..., x_i +_2 x_j, ...)_N$ yields the null string $O_N = (00...0)_N$ when $S_i = S_j$, or when they are different (and $N \geq 2$) generates a *new* string that differs from either of them. If this fails to produce novelty, we invoke the complementation operation defined by $\neg S_i = (..., x_i +_2 1, ...)_N$ applied to either of the initial strings. Whenever either of these operations generates a new string we adjoin it to $\mathcal{U}$ and continue. Otherwise, if we have still failed to generate novelty, the careful reader will realize that we have achieved a situation in which

$$D_N S_1 S_2 = S_3 = \neg S_1 \neg S_2 \tag{1}$$

Our final test is whether the number of 0's in S_3 is equal to the number of 1's. If we fail all these tests, we TICK and all strings are augmented by one random bit. This all there is to our growing universe! The rest is interpretation.

The basic paradigm we use for connecting our model to laboratory experience is drawn from high energy physics. We consider two *counters* separated by a macroscopic distance S which *fire* sequentially, the two firings being separated by a macroscopic time interval T. Each firing then occurs in a macroscopic space-time volume $\Delta x \Delta y \Delta z \Delta t$ which we will never allow to shrink to zero. We have no "points"; our concept of a macroscopic event is similar to that of Whitehead[9] but with no implication of a continuum limit. Nevertheless we can still define *velocity* by $v = S/T$ to arbitrarily high precision simply by separating the two counters far enough. To connect this concept to our bit string model we extend our definition of the velocity of a labeled address string to a subsegment with $b < B$ bits; as before $b = N^1 + N^0$ bits, where N^1 is the number of 1's and N^0 the number of 0's,and $v = (N^1 - N^0)/b$, or for an ensemble of address strings with the same label by the average over the ensemble $v = < N^1 - N^0 > /b$. Our next point of contact with the bit string universe is to assume that the two events are connected by a random walk of b steps where $p = < N^1 > /b$ is the probability of taking a step in one direction and $q = < N^0 > /b$ is the probability of taking a step in the other direction (direction being defined macroscopically by the time sequence of the firing of the counters). With this definition we that velocities must lie between -1 and +1, consistent with the experimental fact that no particle velocities can exceed the limiting velocity c; clearly we have established c as our dimensional unit for velocity.

The fact that there is as yet no way to define spacial direction in our bit string universe (all address strings will occur with equal probability), then allows us to construct the Poincare transformations between coordinate systems defined by the firing of counters in the usual way. We will see below that the combinatorial hierarchy allows us to define only *four* classes of events, so our basic space of description must be 3+1 Minkowski space, again in agreement with experience. Of course, once we have a richer variety of quantum numbers, we can construct multi-dimensional phase spaces, but the basic laboratory space remains 3+1. To introduce *mass* into our model we assume that to each label there corresponds a mass connected to the step length in the random walk l, which in a coordinate system where the random walk has zero velocity is $l_0 = h/mc$ assumed to be a Lorentz invariant. We will prove below that h, which is so far only a constant with the dimensions of action, is indeed Planck's constant. In a moving coordinate system the step length will be Lorentz contracted: $l = l_0[1-v^2/c^2]^{1/2}$. We now introduce two new coordinate system dependent quantities E and p connected to the invariant m by $E^2 - p^2c^2 = m^2c^4$. This allows us to define E in terms of our step length by $l = hc/E$, and implies a second length $\lambda = h/p$. Thus the quantization of our step lengths will become our explanation for the quantization of energy, and the sequential character of the steps will allow us to derive the deBroglie wave length. Having introduced these quantities connected to our basic counter paradigm we can obviously go on to define energy-momentum conserving collisions and measure mass ratios in the usual way. For this we need the additional interpretive postulate that only vertices and scatterings in the bit string universe which conserve *vector* momentum $\vec{p} = m\vec{v}/[1-v^2/c^2]^{1/2}$ will lead to the firing of counters. This completes the rules we need to establish conventional relativistic particle kinematics.

The original treatment by Stein[10] followed another route. He notes that the standard deviation from the peak in a biased random walk is given by $\sigma(v,b) = (bpq)^{1/2} = (b/4)^{1/2}[1-v^2]^{1/2}$. He goes on to show that this contraction factor and the principle of relativity then lead to the Lorentz transformations for his random walk model. This alternative is, we believe, consistent[11–12] with our current treatment, but feel that the arguments given above will be easier for most physicists to follow.

Our next step is to note that, since our basic connection to laboratory experience is through counters that always will enclose many steps in a random walk, we must consider not a singe labeled ensemble, but all ensembles consistent with the same step length. We construct these as coherent ensembles by assuming that in one time interval $\delta t = l/c$ an element of the random walk moves one step, and that in k steps the peak of the distribution moves with velocity c/k to the previous position of the next ensemble in the coherent ensemble of ensembles. We then have a second velocity $v_{ph} = kc$ corresponding to all steps taken in the *same* direction. If we now consider such a coherent ensemble of ensembles incident on a screen with two slits a distance d apart, the most probable positions for the peaks to line up on a detector array a distance D from the slits are at x_n given by $x_n = n\lambda D/d$. Thus we have the equivalent of deBroglie wave interference established on a digital basis and can confidently associate our quantized step length with the Einstein-deBroglie quantization condition $\lambda_{ph} = hc/E$ and our coherence length with the relativistic deBroglie wavelength $\lambda = h/p$.

Our next step is to connect the random walks to a wave theory. Consider a counter centered at $z = 0$ and extending a distance Δz on either side. So far all we know is that for one velocity we have a sequence of steps which can be represented by $\delta[(nz/\lambda) - (ct/\lambda_{ph})] = \delta[(npz - Et)/h]$. But if the counter fires at $t = 0$ these must be absent outside the spacial limits defined above. Hence we must introduce an *amplitude* $f(p)$ and sum over different values of p to meet this boundary condition. This is a critical step, as then $f(p)$ must have negative as well as positive values, and *cannot* be interpreted as a *classical* probability. Clearly we must require that

$$\int_{-\infty}^{+\infty} dp f(p)\ \Sigma_{-N}^{+N} \delta(npz) = [\Theta(z + \Delta z) - \Theta(z - \Delta z)]/2\Delta z \tag{2}$$

In contrast, for a conventional wave theory (with $h/2\pi = 1 = c$) we would have that

$$\int_{-\infty}^{+\infty} dp f(p) e^{ipz} = [\Theta(z + \Delta z) - \Theta(z - \Delta z)]/2\Delta z \tag{3}$$

Therefore, by Fourier inversion

$$(1/2\pi) \int_{-\infty}^{+\infty} dz e^{ip'z} \int_{-\infty}^{+\infty} dp f(p) e^{ipz} = \int_{-\infty}^{+\infty} dp \delta(p - p') f(p') \tag{4}$$

and hence

$$f(p') = (1/4\pi p'\Delta z)[e^{ip'\Delta z} - e^{-ip'\Delta z}] = (i/2\pi p'\Delta z)sin(p'\Delta z) \tag{5}$$

But the *mathematical* operation of Fourier inversion can just as well be applied to Eq. (2). Doing so, we recover Eq.(4) plus correction terms of order $(1/N)$, which proves the equivalence of our bit string model to a wave theory to this order. Further, we can now derive the Heisenberg uncertainty relations for continuum variables in the usual way. Finally, since we have been forced to introduce ***probability amplitudes*** rather than ***probabilities*** by our counter boundary condition, our connection to experiment must include the usual Born interpretation of the square of the amplitude as a ***probability density***. Well known interference effects in scattering then require the amplitudes to be complex and the rule to apply to the absolute square of the amplitude. Thus we claim to have proved that we have constructed free particle quantum wave mechanics on a digital basis as an ***approximate*** theory.

Since we now have free particle wave functions, we can invoke a previous construction of $N-$particle relativistic scattering theory[13] which allows the conventional scattering amplitude to be interpreted as a purely ***kinematic*** (i.e. descriptive) quantity. The dynamics of the theory are then provided by relativistic Faddeev-Yakubovsky integral equations, which guarantee the unitarity of the amplitudes. We derive the driving terms for these equations from our bit string model, and make contact with a minimal relativistic scattering theory previously developed[3,4]. The minimal unitary two particle scattering amplitude in this theory for an intermediate ***s-channel*** state of mass μ with (for equal masses) $s = 4(q^2 + m^2)$ is $g^2/[(m^2 - \mu^2/4)^{1/2} - (m^2 - s/4)^{1/2}]$. By allowing particle and quantum to bind (kinematically) to make a state with the same mass and quantum numbers as the particle, a model which comes directly from our bit string universe, we derive two particle relativistic scattering equations that have the Lippmann-Schwinger equation for a Yukawa "potential" as the well defined non-relativistic limit. Hence we recover a first approximation to nuclear physics, and in the zero quantum mass limit Rutherford scattering and the Bohr atom. Then by interpreting one of our dichotomous quantum numbers in the bit string address as spin, we get atomic physics.

We now return to the box in our basic program (Fig. 2) called CONSTRUCT LABELS... which does not affect the running of the universe, but now becomes part of the *interpretive* schema. As we have seen above, the lowest level of the hierarchy has two linearly independent basis vectors and hence $2^2 - 1 = 3$ DCsS's. We map these by 2×2 matrices providing three basis strings for the second level; the second level gives $2^3 - 1 = 7$ basis strings for the third level, and the third level with $2^7 - 1 = 127$ elements gives $2^{127} \simeq 1.7 \times 10^{38}$ elements in the fourth level. Since $(256)^2 \ll 1.7 \times 10^{38}$ there are no where near enough mapping matrices to map level four, and the sequence *terminates*.

This construction was created by Parker-Rhodes in response to a query by Bastin as to how to generate a sequence with cardinals of a few, a few hundred, some large number, *and stop*, and interpreted by Bastin[1] as giving the scale constants of physics (3 : superstrong, quarks, the three dimensions of space ???; strong : $3 + 7 = 10 \simeq hc/2\pi f^2 = 1/0.08$?[14] ; electromagnetic : $10 + 127 = 137 \simeq hc/2\pi e^2$; gravitational : $137 + 2^{127} - 1 \simeq 1.7 \times 10^{38} \simeq hc/2\pi G m_p^2$).

The full quantum number scheme which relates this construction to the labels in the bit string universe is still under investigation[6]. Our tentative scheme for the first three levels, making use of the mapping matrices[2] is given in Table II. We see that at level 1 we have two component neutrino theory in which, when we add the address label corresponding to zero mass, has $\nu_L = (10...0)_{16}(111..1)$ establishing our helicity convention. At the combined levels 1 and 2 we have the two helicity states of the photon, coupling to electrons and positrons by the extension of Figure 2, W^+, W^-, Z^0 as vector bosons, and the longitudinal or coulomb photon. At this point the particles and quanta are still massless; reversal of velocity [i.e $(111...1) \rightarrow (000...0)$] does not change the direction of spin, proving that it is indeed a pseudovector. At level 3 we find the baryons of strangeness 0 and ± 1 as the obvious interpretation, and the proper number of and quantum numbers for the usual pseudoscalar (because they are bound states of fermion-antifermion pairs) and vector quanta. We might seem to have a problem with the appearance of two longitudinal or coulomb photons. However if one takes the Wheeler-Feynman point of view that all quanta are ultimately absorbed, the unitarity condition in the minimal unitary scattering theory fixes the mass in terms of the coupling constant, or visa versa. J.V. Lindesay, A. Markevich and G. Pastrana[15] find that in the weak coupling limit for $e^2 \simeq 1/137$ the mass of the photon $m_\gamma \simeq m_e e^{-137}$ which is not in conflict with any known experiments[16] . Then the two $S_z = 0$

photons are simply the vector and scalar photons in a four-component theory, and the problem is solved. With some care, and free use of the minimal unitary scattering theory[4,6], it is possible to show that all the usual Feynman diagram rules apply, and hence that our theory is *CPT* invariant at level 3. At level 4 we will have 16×16 quantum numbers. The problem of getting quark quantum numbers, heavy leptons, or, as looks promising from the numerics, *rishons* will be studied after level 3 is under control.

Independent of the details of this scheme, we see from the basic randomness of our construction that at level 3 the exchange of a "coulomb photon" will occur with probability 1/137 compared to all other alternatives. This allows us to calculate the electron mass as the expectation value of its coulomb energy in a coordinate system at rest by a statistical average $m_e c^2 = < e^2/r >$ using $e^2 = hc/2\pi \times 137$. The calculation itself was originally made by Parker-Rhodes[17] starting from a very different construction of space time and the combinatorial result; we provide here a modification of our previous discussion of this calculation[2]. Taking as our basic mass the baryon mass m_B (*because* of the connection to the gravitational constant G) and noting that the heaviest system to which the coulomb photon system couples directly is a baryon-antibaryon pair, the minimal distance we can consider in a system starting from rest is half a baryon compton wavelength. We therefore scale r by $r = (h/2m_B c)y, 1 \leq y < \infty$. The charge in the lepton must separate by more than r into two lumps which by charge conservation we can write in terms of a dimensionless parameter x as ex and $e(1-x)$, where x is a statistical variable reflecting the fact that we have both charged and neutral leptons and baryons. Hence

$$< e^2/r >= (hc/2\pi \times 137) < x(1-x) > (2m_B/h) < 1/y >= m_l c^2 \qquad (6)$$

and

$$m_B/m_l = 137\pi / < x(1-x) >< 1/y > \qquad (7)$$

Since we have now established our space as necessarily three-dimensional, the discrete steps in y must each be weighted by (1/y) with three degrees of freedom; hence

$$< 1/y >= [\int_1^\infty (1/y)^4 dy/y^2] / [\int_1^\infty (1/y)^3 dy/y^2] = 4/5 \qquad (8)$$

Since the charge must both separate and come together with a probability proportional to $x(1-x)$ at each vertex, the weighting factor is $x^2(1-x)^2$. For one degree of freedom this would give

$$< x(1-x) >= [\int_0^1 x^3(1-x)^3 dx]/[\int_0^1 x^2(1-x)^2 dx] = 3/14 \tag{9}$$

Once the charge has separated into two lumps each with charge squared proportional to x^2 or $(1-x)^2$ respectively, we can then write a recursion relation[2,17]

$$K_n = [\int_0^1 [x^3(1-x)^3 + K_{n-1}x^2(1-x)^4]dx]/[\int_0^1 x^2(1-x)^2 dx] \tag{10}$$

and hence

$$K_n = 3/14 + (2/7)K_{n-1} = (3/14)\Sigma_{i=0}^{n-1}(2/7)^i \tag{11}$$

Therefore, invoking again the three degrees of freedom, we must take $< x(1-x) >= K_3$ and we obtain the Parker-Rhodes result

$$m_B/m_l = 137\pi/[(3/14)[1 + (2/7) + (2/7)^2](4/5)] = 1836.151497... \tag{12}$$

Since the electron and proton are stable for at least 10^{31} years we identify this ratio with m_p/m_e in agreement with experiment, thus setting the basic mass ratio scale for the theory. Whether this mass ratio remains unchanged and we can calculate the masses of *unstable* baryons and bosons from our dynamical theory is under investigation[6].

As already noted, the absolute unit of mass in the theory must be approximately the proton mass because of our identification of $2^{127}+136$ with the inverse gravitational coupling constant. Since the calculation given above is a mass ratio, its success is independent of the absolute value of this unit. The corrections which take us from our single dimensional mass parameter m_B to the empirical value for the proton mass and to the empirical value of the fine structure constant will have to come from level four of the theory, where we must also find a place for the equivalent of quarks and heavy leptons. Since we will then have 256 quantum numbers to play with, this will be challenging but not obviously impossible. Other problems, such as building up the electromagnetic field from our photons and the gravitational field from gravitons (we can obviously make the latter – so far as quantum numbers go – from leptons as spin 2 helicity states) is similar to that of any theory which starts from the weak coupling limit.

The reader immersed in special relativity may be troubled by the ticking universe, which provides a universal time, and the fact that our zero velocity criterion which defines the basic momentum-conserving events ($v_3 = N^1 - N^0 = 0$) would seem to single out a particular coordinate system. We have been led to the construction which places scatterings ***between*** TICKs because we cannot allow our events to have a continuum limit in ***points***; else we would get back to the agony of infinite energy at each point, which it has taken so much hard technical work for quantum field theory to deal with. ***Our*** "virtual" processes occur in the "void" as finite fluctuations which cannot be directly accessed by experiment. We claim this is a strength rather than a weakness. As to the special coordinate system, we claim to have shown that we can still define macroscopic velocities v to arbitrary precision, and derive (or, according to some like Michael Peskin, ***define***) the Lorentz transformation, thus recovering special relativity as a ***macroscopic*** approximation. As to the special coordinate system we claim that empirically there ***is*** such a coordinate system which defines $v = 0$ by the 2.7^oK background radiation. This is no more an embarrassment for us than for special relativity; the fact that it occurs so naturally in our theory we again count as a strength rather than a weakness. Clearly we still have to show that we can get the particle physics right, and then go on to show that the big bang emerges from our initial generation operations. This is a problem for future research. We are encouraged by the fact that we have only one type of mass in the theory, and in that sense have no place for a difference between gravitational and inertial mass. Further, if we do indeed succeed in getting spin 2 gravitons in the weak coupling limit, we can hope to recover gravitational theory from that starting point, a problem already discussed by Weinberg[18] .

Our final point is that by focusing on ***velocity*** rather than space and time as basic we believe we have the correct fundamental starting point for unifying macroscopic quasi-continuous measurement with a digital model, a point of view already stressed by S-matrix theorists. Further, our ticking universe allows us to fuse the special relativistic concept of *event* with the unique and indivisible events of quantum mechanics. Whatever else survives from this attempt to construct a digital model for the universe, we are convinced that this is the correct place to connect relativity with quantum mechanics in a fundamental way. We close by remarking that the cosmological implications of the model are not in conflict with experience.

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Table I

Interpretation of the second level of the combinatorial hierarchy in terms of electrons, positrons and gamma rays

		e_L^-	e_L^+	e_R^-	e_R^+	Q	H	outside	e_L^-	e_L^+	e_R^-	e_R^+	Q	H
inside the hierarchy														
basis	$\gamma_L + e_R^-$	1	1	1	0	-1	-1/2	$e_L^- + e_R^-$	1	0	1	0	-2	0
	γ_L	1	1	0	0	0	-1	$e_L^- + \gamma_R$	1	0	1	1	-1	+1/2
	$\gamma_L + e_R^+$	1	1	0	1	+1	-1/2	e_L^-	1	0	0	0	-1	-1/2
								$e_L^- + e_R^+$	1	0	0	1	0	0
discriminate														
closure	e_R^-	0	0	1	0	-1	+1/2	$e_L^+ + e_R^-$	0	1	1	0	0	0
	e_R^+	0	0	0	1	+1	+1/2	e_L^+	0	1	0	0	+1	-1/2
	γ_R	0	0	1	1	0	+1	$e_L^+ + \gamma_R$	0	1	1	1	+1	+1/2
	γ_0	1	1	1	1	0	0	$e_L^+ + e_R^+$	0	1	0	1	+2	0

quanta $\gamma_L, \gamma_R, \gamma_0$

Table II

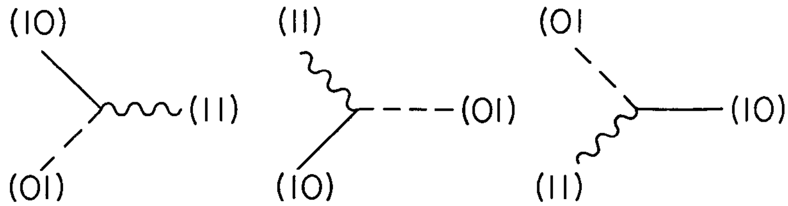
Interpretation of the first three levels of the combinatorial hierarchy in terms of particles (fermions) and quanta (bosons)

		ℓ^o_L	ℓ^o_R	ℓ^-_L	ℓ^+_L	ℓ^-_R	ℓ^+_R	B	$\bar{B}$	B^{ch}_L	B^n_L	B^{ch}_R	B^n_R	i^+_z	i^-_z	i^+_z	i^-_z
Level 1:																	
particles	ν_L	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	$\bar{\nu}_R$	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
quantum	Z_0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Level 2:																	
particles	e^-_L	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	e^+_L	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	e^-_R	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	e^+_R	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
quanta:																	
basis	γ_L	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
	W^-_L	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
	W^+_0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
discriminate																	
closure	W^+_R	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	W^-_0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	γ_R	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
	γ_0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Level 3:																	
particles	p_L	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0
	$\bar{p}_L$	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0
	n_L	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0
	$\bar{n}_L$	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0
	Σ^+_R	0	0	0	0	0	0	1	0	0	0	1	0	1	0	1	0
	Σ^-_R	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	1
	Σ_0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	0	0
	$\bar{\Sigma}_0$	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1

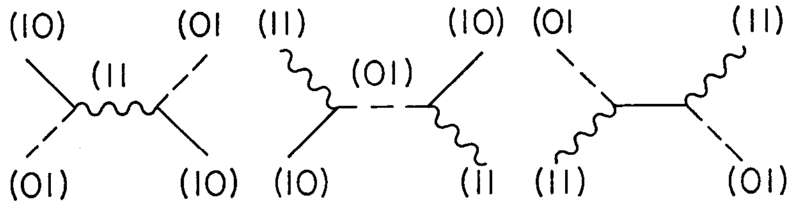
quanta π, ρ, ω, K, K^*, ϕ (1,2,3 level Coulomb (1111111111111111))

FIGURE CAPTIONS

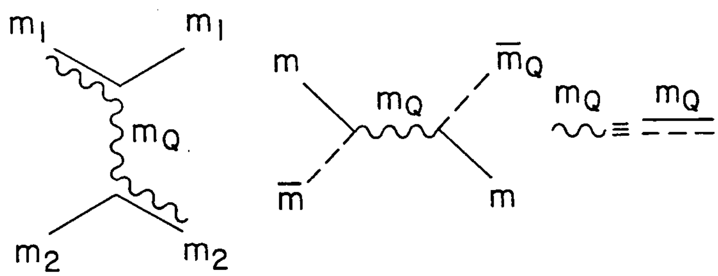
1. (a)The three vertices for a single dichotomous quantum number (level 1). (b) The three events connecting the first three vertices. (c) The driving term for particle-particle scattering and the term unique to particle-antiparticle scattering in the two body sector of the minimal unitary relativistic three particle scattering theory and the driving term in the same theory which occurs only in the particle-antiparticle channel. (d) The two driving terms in the quantum-particle sector.
2. Definitions and flow chart for constructing a growing universe $\mathcal{U}(N, SU)$ containing SU distinct bit strings each containing N bits.



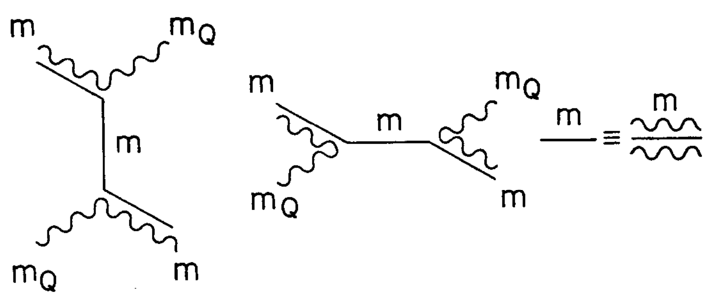
(a) Vertices generated by discrimination or complementation.



(b) Basic scattering events generated by the main program.



(c) Particle-particle and particle-antiparticle scattering in the MUST theory.



(d) Quantum particle scattering in the MUST theory.

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Fig. 1

FLOW CHART FOR PROGRAM UNIVERSE

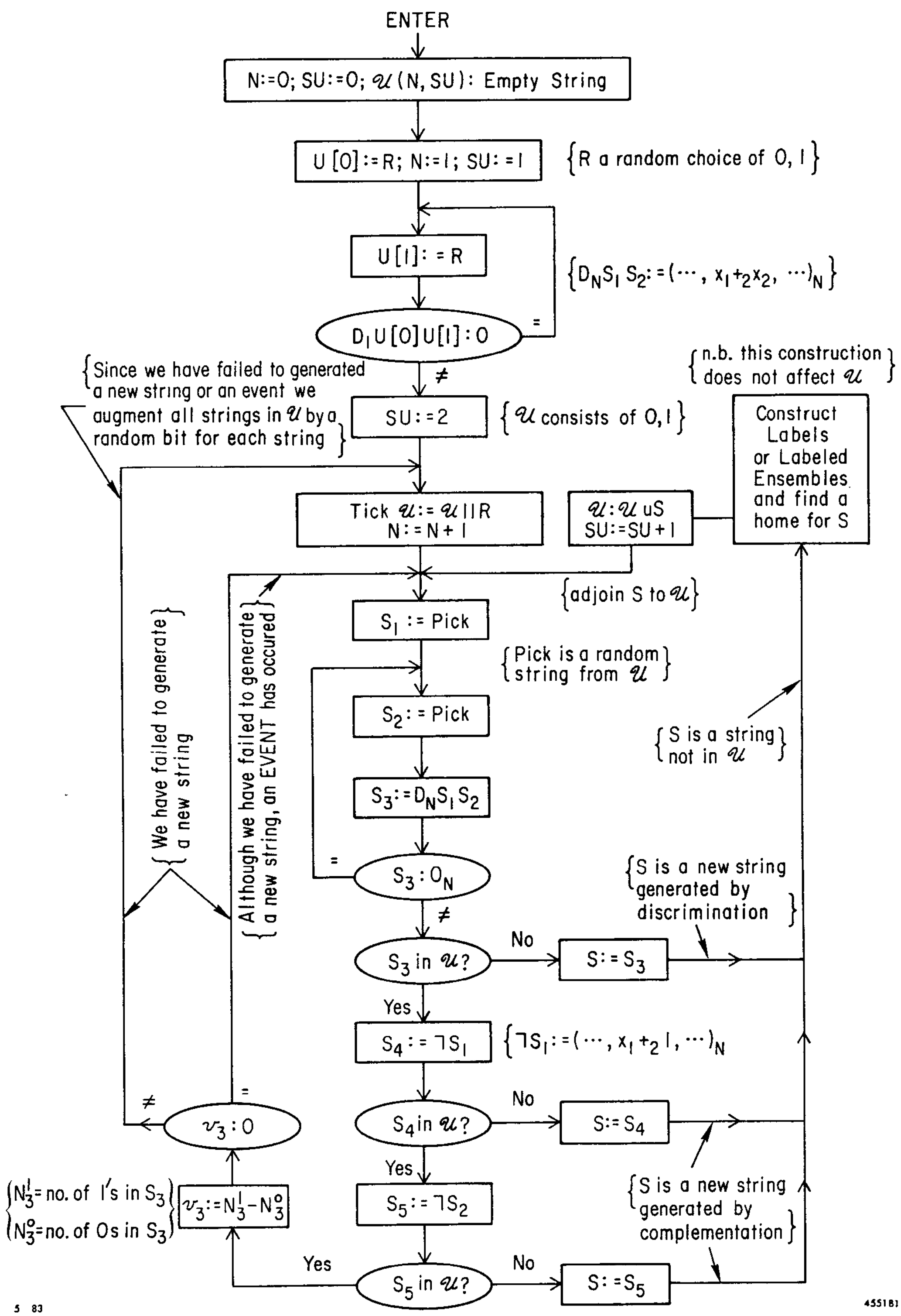

Fig. 2