SLAC–PUB–4730 Rev 3
July 1990
T/Noyes

On the Fine Structure Spectrum of Hydrogen*

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ABSTRACT

Using our discrete relativistic combinatorial bit-string theory of physics in the context of the hydrogen spectrum we *calculate* our first two approximations for the fine structure constant as $\alpha(1) = 1/137$, $\alpha(2) = [1 - \frac{1}{30\times127}]/137 = 1/137.0359674...$; we can then *derive* the Sommerfeld formula.

Key words: discrete physics, combinatorial hierarchy, fine structure constant, Sommerfeld formula

Submitted to *Physics Essays*

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* Work supported by the Department of Energy, contract DE–AC03–76SF00515.

We present here a novel calculation based on an unconventional but actively developing physical theory[1]; a reasonably complete overview of this theory has been published in this journal[2]. The theory asserts that to order α the fine structure constant used to describe the energy spectrum of the hydrogen atom should have the value 1/137. We go on to predict on the same basis that the second order value in the same context is $[1 - \frac{1}{30\times127}]/137 = 1/137.0359\ 674....$, close to the currently accepted value given[3] as "1/137.0359 895(61) [At $Q^2 = m_e^2$. At Q^2 of order m_W^2 the value is approximately 1/128.]". Both the derivation and the calculation will require corrections of order α^3 and $(m_e/m_p)^2$ when extended beyond the context of the hydrogen atom. Since most current theories do not contemplate the possibility of calculating α, although Weinberg[4] has indicated that this should be possible in principle, we must justify our method before presenting the calculation.

Conventional theories take the structure of relativistic quantum mechanics as given. The two empirical constants c and $\hbar$ are connected to the arbitrary historical standards of mass, length and time by various, hopefully self-consistent, means. A third fundamental constant such as the square of the electronic charge or the electron, proton, Planck, ... mass has to be taken from experiment before theoretical "predictions" can be attempted. Often the resulting comparisons with experiment can remain very rough, until supplemented by a generous amount of additional empirical input and theoretical structure. For instance, the high dimension Kaluza-Klein theories coupled to a large number of Yang-Mills fields, when compactified, in effect take the Planck mass $[\hbar c/G]^{\frac{1}{2}}$ as the third dimensional parameter. In this context Weinberg(4) calculates the coupling constants of the fields, which are supposed to include the equivalent of $\alpha, G_F, g_s, ...$ Numerical results are quantitatively inadequate for comparison with experiment. Further modifications of this type of theory, needed to close the gap, often have only a tenuous connection to algorithmic precision or actual laboratory practice. Starting from one of the four "empirical" numbers mentioned above (i.e. $e^2, m_e, m_p, M_{Planck}$) there is nō consensus on how to calculate the other three — a clear requirement for any fundamental physical theory that allows only empirical standards for mass, length

and time, or some equivalent like $c, \hbar$ and m_p to dictate the common units for the inter-comparison of experiments between laboratories. We have recently provided a systematic discussion of how our theory can start from $c, \hbar$ and the Planck mass[5].

Our theory differs in that we claim to be able to *calculate* a first approximation to the ratio of the Planck mass to the proton mass, the ratio of the proton mass to the electron mass, and the ratio of the square of the elementary electromagnetic charge to the product of the unit of action and the limiting velocity. Therefore we can connect our theory to experiment by taking any one of the four accepted values from experiment and calculating a first approximation for the other three. From then on our iterative improvement of the theory is, in principle, much the same as for any other fundamental theory, such as the currently popular "string theories".

Although our methodology looks almost conventional when we describe it above, our practice is significantly different in several ways. In contrast to most "elementary particle" theories, we do *not* take relativistic quantum mechanics for granted. Our "mathematics" relies on the *ordering operator calculus*[6]. We accept the principles of finiteness, discreteness, finite computability, absolute non-uniqueness, and require the formalism to be strictly constructive.[7] The fact that we are able to use our fundamental principles to *construct* (rather than postulate) the limiting velocity and discrete events, and then to *derive* the Lorentz transformations and the non-commutativity of position and velocity gives our theory more explanatory power than the conventional approach. We start from the current practice of physics, construct an uninterpreted (but motivated) model that stands on its own feet as a piece of mathematics, and then construct *rules of correspondence*(7) which allow us to compare this structure and calculations made from it with current theoretical practice and experimental results. Anomalies, ambiguities and discrepancies then call for iteration of the procedure starting anywhere in the chain and moving in either direction, keeping past experience in mind.

The theory that we are iteratively developing started in the 50's, motivated in part by a search for a hierarchical structure that would give clues as to how the scale constants of physics and cosmology might be constructed. This research effort led to the discovery of the *combinatorial hierarchy*[8,9] by A.F. Parker-Rhodes in 1961. The hierarchy is constructed from two recursively generated sequences: $n_{i+1} = 2^{n_i} - 1$ and $m_{i+1} = m_i^2$ starting from $n_0 = 2 = m_0$, which terminate at i=4 because the mapping (see below) connecting the second sequence to the first cannot be constructed beyond that term. This discovery supported no obvious "rule of correspondence" connecting the cumulative number of elements in play at the third ($3 + 7 + 10 = 137$) and fourth ($137 + 2^{127} - 1 \simeq 1.7 \times 10^{38}$) levels as good approximations to the known scale constants $137 \simeq \hbar c/e^2$ and $1.7 \times 10^{38} \simeq \hbar c/Gm_p^2 = [M_{Planck}/m_p]^2$.

The model is conveniently represented by ordered strings of the symbols 0 and 1 (*bit-strings*):

$$\mathbf{a}(S) = (..., b_s^a, ...)_S;\ b_s^a \in 0,1;\ s \in 1,2,....S;\ 0,1,...,S \in \textit{ ordinal integers} \quad (1)$$

which can combine by *discrimination* (XOR) symbolized by "$\oplus$":

$$\mathbf{a} \oplus \mathbf{b} = (..., b_i^{a\oplus b}, ...)_S = \mathbf{b} \oplus \mathbf{a};\ b_i^{a\oplus b} = (b_i^a - b_i^b)^2 \quad (2)$$

or *concatenation* symbolized by "$\|$":

$$\mathbf{a}(S_a)\|\mathbf{b}(S_b) = (....b_i....)_{S_a}\|(....b_j^b...)_{S_b} = (....., b_k^{a\|b}, ...)_{S_a+S_b}$$

$$b_k^{a\|b} = b_i^a,\ i \in 1,2,...,S_a;\ b_k^{a\|b} = b_j^b,\ j \in 1,2,...,S_b, k = S_a + j \quad (3)$$

We take as our model for generating these strings the class of algorithms called *program universe*[10,11] . These pick two arbitrary strings from a universe containing strings of length S, discriminate them, and if the result is not the null string ($b_s^0 = 0$

for all s) adjoin it to the universe; else they concatenate an arbitrary bit, separately chosen for each string, to the growing end of each string. If we think of this bit-string universe as a block of strings of length S and height H, the second operation (called *TICK*) amounts to adjoining an arbitrary column (Bernoulli sequence) and hence $S \rightarrow S + 1$. The first operation (called *PICK*) generates a string from the extant content and adds it as a new horizontal row ($H \rightarrow H + 1$).

Finite sets of non-null bit-strings which *close* under discrimination are called *discriminately closed subsets* (*dcss*). For example, two *discriminately independent* bits-strings (i.e. $\mathbf{a} \oplus \mathbf{b} \neq \mathbf{0}$) generate 3 dcss: $\{\mathbf{a}\}$, $\{\mathbf{b}\}$, $\{\mathbf{a}, \mathbf{b}, \mathbf{a} \oplus \mathbf{b}\}$. The three member set closes under discrimination because any two members discriminate to the third. Similarly 3 discriminately independent bit-strings generate 7 dcss:

$$\{\mathbf{a}\},\ \{\mathbf{b}\},\ \{\mathbf{c}\}$$

$$\{\mathbf{a}, \mathbf{b}, \mathbf{a} \oplus \mathbf{b}\};\ \{\mathbf{b}, \mathbf{c}, \mathbf{b} \oplus \mathbf{c}\};\ \{\mathbf{c}, \mathbf{a}, \mathbf{c} \oplus \mathbf{a}\} \tag{4}$$

$$\{\mathbf{a},\ \mathbf{b},\ \mathbf{c},\ \mathbf{a} \oplus \mathbf{b},\ \mathbf{b} \oplus \mathbf{c},\ \mathbf{c} \oplus \mathbf{a},\ \mathbf{a} \oplus \mathbf{b} \oplus \mathbf{c}\}$$

Clearly, given j non-null discriminately independent strings one can form $2^j - 1$ dcss. If one starts with two discriminately independent bit-strings of length 2 [(01), (10) *or* (01), (11) *or* (11), (10)] and forms the three dcss, these can be mapped by three non-singular $\mathbf{2 \times 2}$ matrices which have them as their only eigenvectors and which are discriminately independent to provide three basis elements for a new level. This mapping can be repeated using $\mathbf{4 \times 4}$ matrices with $7 = 2^3 - 1 < 16$ non-singular and discriminately independent exemplars, and once again using $\mathbf{16 \times 16}$ matrices because $127 = 2^7 - 1 < 256$; however the mapping cannot be carried further because $\mathbf{256 \times 256}$ matrices have only 256^2 discriminately independent exemplars and $256^2 \ll 2^{127} - 1$. This is still the simplest way to explain how the combinatorial hierarchy can be generated and why it terminates.

Although our *program universe* algorithm need not explicitly contain the matrix mapping proposed by Parker-Rhodes, the fact that the strings grow by concatenation of bits at only one end and the property of discriminate closure explained above insures that we will automatically generate many different bit-string representations of the combinatorial hierarchy in the early parts of the strings. We use these early parts of the string as *labels* for the rest of the string. We employ these labels to construct quantum numbers and the rest of the string to construct our discrete version of space-time, as we explain in more detail in Ref.2 and later work[12].

Events are defined by the constraint that either three or four strings combine to the null string. If we take as our measure the number of 1's in a string of length S (the Hamming measure) this together with our definition of event insures that these measures for the three or four strings satisfy a triangle inequality and can be used to define a metric. For two independently generated measures in a locally flat *discrete* space (d-space), these combine in quadrature to a third measure $c^2 = a^2 + b^2$, but the value of c as a "square root" may not exist. However, we can always define symmetric factors $c^2 = (c' + f)(c' - f) = (c')^2 - f^2$ where f is a rational fraction less than c' which has to be consistently assigned in context.

Once we have constructed the label-content concatenation, we can interpret the situations where PICK leads to a non-null string (i.e. $\mathbf{c} = \mathbf{a} \oplus \mathbf{b}$, or equivalently $\mathbf{a} \oplus \mathbf{b} \oplus \mathbf{c} = \mathbf{0}$) as the production (eg by pair annihilation or bremmstrahlung) or absorption of a single label which either initiates or terminates a propagation of the label that continues for (or ends after) some finite number of TICKs. This is a discrete model for a Feynman vertex. The completed process combining two such vertices models a 4-leg diagram $\mathbf{a} \oplus \mathbf{b} \oplus \mathbf{c} \oplus \mathbf{d} = \mathbf{0}$ which we call a 4-event. The choice of this criterion is not arbitrary. McGoveran (Ref 6, Theorem 13) has shown that any discrete space of D "homogeneous and isotropic" dimensions synchronized by a universal ordering operator can have no more than *three* indefinitely continuable dimensions; three separate out and the others "compactify" after a surprisingly small number of constructive operations. This theorem is also discussed

in Ref. 2.

A tentative rule of correspondence between the last two cardinals of the combinatorial hierarchy and a known result in relativistic quantum field theory was suggested by HPN[13] in 1973. HPN argued that Dyson's calculation[14] of the maximum number of terms in the renormalized QED perturbation theory series in $\alpha = e^2/\hbar c \approx 1/137$ which are meaningful (137, because the series with $\alpha \rightarrow -\alpha$ diverges beyond that point) shows that the maximum number of charged particle pairs which can be *counted* within their own compton wavelength is $137 \simeq (2mc^2)^{-1}[e^2/(\hbar/2mc)]^{-1} = \hbar c/e^2$. The same argument applied to gravitation shows that the maximum number of gravitating baryons of protonic mass which can be counted within their own compton wavelength is $\hbar c/Gm_p^2 = 1.7 \times 10^{38} \simeq 2^{127}$. Thus the two largest combinatorial hierarchy integers can be interpreted as counting numbers of particles in an appropriate physical context; *why* this should be so remained a mystery until a full physical context had been worked out.

Once the bit-string representation of quantum events was connected to discrete quantum number conservation laws, relativistic 3-momentum conservation and relativistic Bohr-Sommerfeld quantization, it became possible[2] to construct a rule of correspondence connecting the first three levels of the hierarchy to the first generation of the standard model of quarks and leptons. The current rule is that the first level has two chiral neutrinos and an associated quantum (3 labels), that the second level has electrons, positrons, gamma rays and the coulomb interaction (7 labels), and that the third level has up and down quarks with associated gluons in a color-confined octet ($16 \times 8 - 1 = 127$ labels). [Color confinement is proved in our context by the extension of McGoveran's Theorem to label-content "space".] In the absence of further information, the coulomb interaction will occur with a probability of 1/137 in all events that must contain the first three levels. Corrections will occur when we must also consider less probable complexities bought in, for example, by the 256^2 possibilities that occur in the mapping of level 3 when four fermions engage directly in an event. These we associate with weak-electromagnetic unification and calculate a first approximation for the Fermi

"coupling constant" to be $\sqrt{2}G_F m_p^2 = 1/256^2$; our first approximation for the weak angle is $sin^2\theta_{Weak} = \frac{1}{4}$. The overall context in which the calculation we now describe is set is summarized in the **Table of Results.**

In our bit-string model, as we have already explained, part of the string (the *label*) represents the quantum numbers generated by the combinatorial hierarchy as discussed above and the remainder of the string (of *content* length n) can represent a biased random walk between events in which the l's represent k steps in one direction and the 0's represent $n - k$ steps in the other. Generalizing from Stein[15] we use a rule of correspondence which requires each step in any content string or strings allowed in context to be executed at the limiting velocity c and have length h/mc; hence the velocity between events is $\beta c = [\frac{2k}{n} - 1]c$. If we wish to model "constant velocity", this restricts content strings of length nN to have kN 1's, defining the deBroglie wavelength periodicity N as the "positions" where events *could* (but need not) occur. Because the step-wise change in "position" h/mc implies a change in momentum mc, both of which can be reversed at the next step enclosing an area h in phase space, or more generally enclosing an area nNh when we return to a cyclic starting point after nN steps, we have derived relativistic Bohr-Sommerfeld quantization from our model, including the *zitterbewegung* associated with the string mass specified by the system label.

Most of this background is not directly invoked in the algebraic steps needed to obtain our result. But we have found that, without such an explanation, most physicists cannot see why these algebraic steps lead to a *physical* and not just a mathematical result. It may be easier to follow our reasoning if one goes back to the stage in quantum mechanics when Bohr computed the relativistic formula for the energy levels of the hydrogen atom[16]. Sommerfeld was able to extend this result[17] to compute, in agreement with experiment, the known fine structure splitting. Bohr had made use of the correspondence principle to tie his model to "classical orbits" at *large* space-time separations between electron and proton, but was well aware of the fact that these classical ideas did not apply to the low lying states. He was also well aware of the fact that his "circular orbits" in

such cases did *not* imply "flat atoms" but in fact described spherically symmetric systems in three-space — a realization that is all too often lost in elementary discussions of the "Bohr atom". Because he could not rely on his classical space-time intuition, his calculation concentrated on the quantum rules that connect an abstract *energy level model* of the atom to the *observed* transition frequencies as interpreted from the wavelengths of the line spectrum. It was this concentration on observed frequencies rather than spacial models that, in the hands of Heisenberg, led to matrix mechanics. Our calculation is made in the same spirit, but employs our labeled bit-string construction rather than the correspondence principle to insert the quantum rules into the calculation.

We consider a system composed of two masses, m_p and m_e — which we claim to have computed from first principles[5] in terms of $\hbar, c$ and G — and identified by their labels using our quantum number mapping onto the combinatorial hierarchy[2]. In this framework, their mass ratio (to order α^3 and $(m_e/m_p)^2$) has also been computed using only $\hbar, c$ and 137. However, to put us in a situation more analagous to that of Bohr, we can take m_p and m_e from experiment, and treat $1/137$ as a counting number representing the coulomb interaction; we recognize that corrections of the order of the square of this number *may* become important one we have to include degrees of freedom involving electron-positron pairs. We attribute the binding of m_e to m_p in the hydrogen atom to coulomb events, i.e. only to those events which involve a specific one of the 137 labels at level 3 and hence occur with probability $1/137$; the changes due to other events average out (are *indistinguishable* in the absence of additional information). We can have any periodicity of the form $137j$ where j is any positive integer. So long as this is the only periodicity, we can write this restriction as $137j$ *steps* $= 1$ *coulomb event.* Since the internal frequency $1/137j$ is generated independently from the *zitterbewegung* frequency which specifies the mass scale, the normalization condition combining the two must be in quadrature. We meet the bound state requirement that the energy E be less than the system rest energy $m_{ep}c^2$ (where $m_{ep} = m_e m_p/(m_e + m_p)$ is used to take account of 3-momentum conservation) by

requiring that $(E/\mu c^2)^2[1 + (1/137N_B)^2] = 1$. If we take $e^2/\hbar c = 1/137$, this is just the relativistic Bohr formula[16] with N_B the principle quantum number.

Since most of our readers have never encountered this formula, and might have trouble chasing through the units in which it is expressed starting from the 1915 paper, we derive it in a modern way[5] by treating the bound state as a pole in the relativistic wave function — or S-matrix. The basic S-Matrix point of view associates a bound or resonant state of any two-particle system with a pole at invariant 4-momentum squared s_0 in the two-particle momentum-space wave function $\phi(s, s_0)$ whose residue defines the "coupling constant" f^2. In the narrow width approximation this translates to

$$\phi(s, s_0) = \frac{f^2\mu}{s - s_0} \tag{5}$$

Assuming the state contains only two particles of mass m_1, m_2 yields the normalization condition

$$\int_{(m_1+m_2)^2}^{\infty} ds|\phi(s, s_0)|^2 = 1 \tag{6}$$

which forces us, for dimensional reasons, to include some mass μ in the definition of the residue if we wish (in analogy with $e^2/\hbar c$) to keep the coupling constant f^2 dimensionless. By performing the integration we obtain a simple connection between masses and coupling constants

$$(f^2\mu)^2 = (m_1 + m_2)^2 - s_0 \tag{7}$$

Note that the *magnitude* of f^2 is not seriously restricted by this algebraic connection until we have inserted more information. We assert that this starting point is *non-perturbative* and rests only on *unitarity* and relativistic quantum mechanics in a finite particle number space. If we take $f^2 = e^2/\hbar c = \alpha \simeq 1/137$, take the free system mass equal to the reduced mass "$m_1 + m_2$" $\rightarrow m_{ep} = \frac{m_e m_p}{m_e + m_p}$ (which implies that $s_0 = (m_{ep} - \epsilon_{Bohr})^2$) and use this also as the reference mass μ, we obtain once again the relativistic Bohr formula.

The Sommerfeld model for the hydrogen atom (and, for superficially different but profoundly similar reasons,[18] the Dirac model as well) requires two *independent* periodicities. If we take our reference period j to be integer and the second period s to differ from an integer by some rational fraction Δ, there will be two minimum values $s_0^{\pm} = 1 \pm \Delta$, and other values of s will differ from one or the other of these values by integers: $s_n = n + s_0$. This means that we can relate ("synchronize") the fundamental period j to this second period in two different ways, namely to

$$137j\frac{steps}{(coulomb\ event)} + 137s_0\frac{steps}{(coulomb\ event)} = 1 + e = b_+ \tag{8}$$

or to

$$137j\frac{steps}{(coulomb\ event)} - 137s_0\frac{steps}{(coulomb\ event)} = 1 - e = b_- \tag{9}$$

where e is an event probability. Hence we can form

$$a^2 = j^2 - s_0^2 = (b_+/137)(b_-/137) = (1 - e^2)/137^2 \tag{10}$$

Note that if we want a finite numerical value for a, we cannot simply take a square root, but must determine from context which of the symmetric factors [i.e. $(1 - e)$ or $(1 + e)$] we should take (c.f. the discussion about factoring a quadratic above). With this understood, we write $s_n = n + \sqrt{j^2 - a^2}$.

We must now compute the probability e that j and s are mapped to the same label, using a single basis representation constructed within the combinatorial hierarchy. We can consider the quantity a as an event probability corresponding to an event **A** generated by a global ordering operator which ultimately generates the entire structure under consideration. Each of the two events j and s can be thought of as derived by sampling from the same population. That population consists of 127 strings defined at level three of the hierarchy. In order that j and s be independent, at least the last of the 127 strings generated in the construction of $\bar{s}$ (thus completing level three for s) must not coincide with any string generated in the construction of j. There are 127 ways in which this can happen.

There is an additional constraint. Prior to the completion of level three for s, we have available the $m_2 = 16$ possible strings constructed as a level two representation basis to map (i.e. represent) level three. One of these is the null string and cannot be used, so there are 15 possibilities from which the actual construction of the label for s that completes level 3 are drawn. The level can be completed just before or just after some j cycle is completed. So, employing the usual frequency theory of probability, the expectation e that j and s as constructed will be indistinguishable is $e = 1/30 \times 127$.

In accordance with the symmetric factors $(1 - e)$ or $(1 + e)$ the value e can either subtract from or add to the probability of a coulomb event. These two cases correspond to two different combinatorial paths by which the independently generated sequences of events may close (the "relative phase" may be either positive or negative). However we require only the probability that all s_0 events be generated within one period of j, which is $1 - e$. Hence the difference between j^2 and s^2 is to be computed as the "square" of this "root", $j^2 - s_0^2 = (1 - e)^2$. Thus, for a system dynamically bound by the coulomb interaction with two internal periodicities, as in the Sommerfeld or Dirac models for the hydrogen atom, we conclude that the value of the fine structure constant to be used should be

$$\frac{\mathbf{1}}{\mathbf{a}} = \frac{\mathbf{137}}{\mathbf{1 - \frac{1}{30 \times 127}}} = \mathbf{137.0359\ 674...}$$

in comparison to the accepted empirical value of[3]

$$\frac{1}{\alpha} \simeq 137.0359\ 895(61)$$

Now that we have the relationship between s, j and a, we consider a quantity H' interpreted as the energy attribute expressed in dynamical variables at the $137j$ value of the system containing two periods. We represent H' in units of the invariant system energy μc^2. The independent additional energy due to the shift of s_n relative to j for a period can then be given as a fraction of this energy by

$(a/s_n)H'$, and can be added or subtracted, giving us the two factors $(1-(a/s_n)H')$ and $(1+(a/s_n)H')$. These are to be multiplied just as we multiplied the factors of a above, giving the (elliptic) equation $(H')^2/(\mu^2c^4)+(a^2/s_n^2)(H')^2/\mu^2c^4=1$, Thanks to the previously derived expression of $s=n+s_0$ this can be rearranged to give us the Sommerfeld formula[17]

$$H'/\mu c^2=[1+\frac{a^2}{(n+\sqrt{j^2-a^2})^2}]^{-1/2}$$

Several corrections to our calculated value for α can be anticipated, depending on context. As noted above, we have a first approximation for the Fermi constant and for the weak angle, each of which disagrees with currently accepted values by a few percent. Just how weak-electromagnetic unification takes shape in our developing theory could lead to problems at this level of accuracy. More immediately, the Sommerfeld formula uses the "system mass" which, naively, is $\bar{\mu}=m_em_p/(m_e+m_p)$, and hence suggests that there may be corrections of order $(m_e/m_p)^2$. At the level of accuracy of our calculation, these can be ignored in hydrogen, but will be significant in muonium. In QED, these corrections depend on the sum of the squares of the two finite masses, which is consistent with our rule that requirestwo independent quantities to add in quadrature. If we cannot derive the appropriate correction, our theory could be in serious trouble. Another point that bears watching is whether there is spin dependence at this level of accuracy. Clearly the calculation presented here cannot apply to positronium, or to the "Lamb shift", but these effects go beyond order α^2 in conventional QED, and presumably for us as well. Our theory is frangible if we cannot meet these challenges, just as QED was in the late 40's. We ask the reader to consider whether the conceptual advantages and quantitative results our approach has already demonstrated provide sufficient incentive for engaging in the hard work needed to extend our theory to higher approximations and to the systematic calculation of other physically dimensionless parameters.

Acknowledgements

This work was supported in part by the Department of Energy, contract DE-AC03-76SF00515.

Revised version received on July 18, 1990.

[Resume in French to be supplied by *Physics Essays*]

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Table of Results, June, 1990

General structural results

- 3+1 asymptotic space-time
- combinatorial free particle Dirac wave functions
- supraluminal synchronization and correlation *without* supraluminal signaling
- discrete Lorentz transformations for event-based coordinates
- relativistic Bohr-Sommerfeld quantization
- non-commutativity between position and velocity
- conservation laws for Yukawa vertices and 4- events
- crossing symmetry, CPT, spin and statistics

Gravitation and Cosmology

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- electromagnetic and gravitational unification
- the three traditional tests of general relativity
- event horizon
- zero-velocity frame for the cosmic background radiation
- mass of the visible universe: $(2^{127})^2 m_p = 4.84 \times 10^{52}\ gm$
- fireball time: $(2^{127})^2 \hbar/m_p c^2 = 3.5$ million years
- critical density: of $\Omega_{Vis} = \rho/\rho_c = 0.01175$ $[0.005 \leq \Omega_{Vis} \leq 0.02]$
- dark matter $\doteq$ 12.7 times visible matter [10??]
- baryons per photon $= 1/256^4 = 2.328... \times 10^{-10}$ $[2 \times 10^{-10}?]$

Unified theory of elementary particles

- quantum numbers of the standard model for quarks and leptons

with confined quarks and exactly 3 weakly coupled generations

- gravitation: $\hbar c/Gm_p^2 = [2^{127} + 136] \times [1 - \frac{1}{3\cdot7\cdot10}] =$
  $1.70147...[1 - \frac{1}{3\cdot7\cdot10}] \times 10^{38} = 1.6934... \times 10^{38}$ $[1.6937(10) \times 10^{38}]$
- weak-electromagnetic unification:
  $G_F m_p^2/\hbar c = (1 - \frac{1}{3\cdot7})/256^2\sqrt{2} = 1.02\ 758... \times 10^{-5}$ $[1.02\ 684(2) \times 10^{-5}]$;
  $sin^2\theta_{Weak} = 0.25(1 - \frac{1}{3\cdot7})^2 = 0.2267...$ $[0.229(4)]$
  $M_W^2 = \pi\alpha/\sqrt{2}G_F sin^2\theta_W = (37.3\ Gev/c^2 sin\ \theta_W)^2$; $M_Z cos\ \theta_W = M_W$
- the hydrogen atom: $(E/\mu c^2)^2[1 + (1/137N_B)^2] = 1$
- the Sommerfeld formula: $(E/\mu c^2)^2[1 + a^2/(n + \sqrt{j^2 - a^2})^2] = 1$
- the fine structure constant: $\frac{1}{\alpha} = \frac{137}{1 - \frac{1}{30\times127}} = 137.0359\ 674...[137.0359\ 895(61)]$
- $m_p/m_e = \frac{137\pi}{\frac{3}{14}\left(1+\frac{2}{7}+\frac{4}{49}\right)\frac{4}{5}} = 1836.15\ 1497...$ $[1836.15\ 2701(37)]$
- $m_\pi^\pm/m_e = 275[1 - \frac{2}{2\cdot3\cdot7\cdot7}] = 273.1292...$ $[273.12\ 63(76)]$
- $m_{\pi^0}/m_e = 274[1 - \frac{3}{2\cdot3\cdot7\cdot2}] = 264.2\ 1428..$ $[264.1\ 160(76)]$
- $(\overline{G}_{\pi N}^2 m_{\pi^0})^2 = (2m_p)^2 - m_{\pi^0}^2 = (13.86811 m_{\pi^0})^2$

[( )] = empirical value (error) or range