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WHAT IS TO BE DONE*

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ABSTRACT

Steps which can be taken in our scattering theory, unification schemes, cosmology, QED and QCD which will advance the progress of our scientific revolution are presented.

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1. WHERE WE ARE

ANPA and ANPA WEST are poised to make a scientific revolution. Our strategic position[1] is summarized on the last page of this paper. Clearly we have opened up a new line of attack on many of the most exciting unsolved problems in contemporary physics and cosmology. Yet for most physicists the fact that we have constructed first order results for most of the underlying physical parameters any fundamental theory needs to contain and employ in an understandable way will *not* compel them to join with us. For one thing, we need to demonstrate that the discrepancies between these results and experiment (accepted experimental values are given in [ ] in the tabulation) can be calculated or at least estimated. But most will wait until we have "predicted" some number that disagrees with their theories and which subsequent measurements support.

The first part of the requirement has been met to order $(1/137)^2$ in the case of the hydrogen atom by David McGoveran[2,3] by deriving the Sommerfeld formula and calculating the value of the fine structure constant which our theory requires to appear in it. The overall tactical position in this specific engagement has been presented elsewhere[4]. Since then the first referee has rejected the paper. His words and our tentative suggestion as to how to regroup for a counter-attack are given as an Appendix to this paper. The current fluid situation presents you with the opportunity to join the attack, engage the flanks, seek a better tactical or strategic alternative,.... Clearly McGoveran and I are committed to continue with this engagement until we achieve publication or a final rejection; we will probably have to fight it out on these lines all year.

McGoveran and I will obviously be grateful for tactical and strategic support; however, it does *not* follow that this is the best point for other members of our organization to engage the enemy. In what follows I attempt a broader survey of where we need to firm up the rather shaky structure so far achieved, and where — with luck and a lot of hard work — breakthroughs comparable to the fine structure calculation might be achieved. Since the mathematical[5] and philosophical[6] foundations have been presented in some detail elsewhere I leave these aspects to others and concentrate here on physics and cosmology. I assume in what follows that the reader has read Reference 1, and has it on hand.

2. SCATTERING THEORY

In thinking about where to start giving more technical content to our theory so as to be able to make a quantitative attack on problems in gravitation, dark matter, weak-electromagnetic unification, QED, running quark and gluon masses,.... it became clear to me that our particle scattering theory has to be articulated with much more care. Until recently I had so much else to do that I couldn't address this problem properly. The fact we had derived the "propagator" of relativistic scattering theory[7] from the counter paradigm and our version of Stein's biased random walk[8] and could relate it to the relativistic finite particle number scattering theory[9] had to suffice. The problem came to a head at ANPA 10 when I wasn't able to demonstrate to Kilmister's satisfaction that our bit string model for scattering does indeed conserve discrete 3-momentum. Subsequent discussion did not completely resolve the matter. I sketch here how 3-momentum conservation comes about in a *4-event*; more needs to be done.

2.1. KINEMATICS

Recall that our basic constituents are evolving *bit strings* (ordered strings of 0's and 1's) $(a)_{L+n} = (L_a)_L \| (A^a_x)_n$ concatenated from a *label string* $(L_a)_L$ of fixed length L which specifies the quantum numbers and a *content string* $(A^a_x)_n$ taken from an ensemble which can grow in both length n and in the number of content strings as the investigation proceeds. We *discriminate* two strings (for us, necessarily of the same length) by "exclusive or" and introduce the shorthand notation $(a0) = (a), (aa) = (0)$; $(ab) = (ba) \neq (0)$; $(a(bc)) = ((ab)c) = (abc)$ and so on. In this notation, a 4-event is defined by $(abcd) = (0)$. We concern ourselves here only with the six (2,2) channels: $a+b \rightarrow c+d$; $a+c \rightarrow b+d$; $a+d \rightarrow b+c$; $c+d \rightarrow a+b$; $b+d \rightarrow a+d$; $b+c \rightarrow a+d$.

The laboratory situation we are modeling starts with two incoming particles, each selected by one of two counter telescopes leading into the scattering chamber, and two outgoing particles selected by two exit counter telescopes. We assume that the four masses are known, and measure the velocities and the angles. Then 3-momentum conservation cuts the 12 kinematic degrees of freedom $(\vec{p}_a, \vec{p}_b, \vec{p}_c, \vec{p}_d)$ to nine for any particular channel, for example by requiring that $\vec{p}_a + \vec{p}_b = \vec{p}_c + \vec{p}_d$. Define the 4-vectors $P_a = (m_a\gamma_a, m_a\gamma_a\vec{\beta}_a)$ with $P_aP_b = m_a\gamma_a m_b\gamma_b - m_a\gamma_a\beta_a m_b\gamma_b\beta_b cos\theta_{ab}$ and $\gamma^2\beta^2 = \gamma^2 - 1$. Then the three Mandelstam invariants are

$$s_{ab} = (P_a + P_b)^2 = m_a^2 + m_b^2 + 2m_a\gamma_a m_b\gamma_b(1 - \beta_a\beta_b cos\ \theta_{ab})$$

$$t_{ab} = (P_a - P_c)^2 = m_a^2 + m_c^2 + 2m_a\gamma_a m_c\gamma_c(1 - \beta_a\beta_c cos\ \theta_{ac})$$

$$u_{ab} = (P_a - P_d)^2 = m_a^2 + m_d^2 + 2m_a\gamma_a m_d\gamma_d(1 - \beta_a\beta_d cos\ \theta_{ad})$$

and similarly for the exit channels. Momentum-energy conservation imposes the four constraints

$$s_{ab} = s_{cd};\ t_{ab} = t_{cd};\ u_{ab} = u_{cd};\ s_{ab} + t_{ab} + u_{ab} = m_a^2 + m_b^2 + m_c^2 + m_d^2$$

Hence, if we know the four masses, the four velocities and any two of the three invariants, all six angles are know in the corresponding coordinate system. Alternatively, if we know two of the angles in addition to the masses and velocities, everything else is fixed. Either approach specifies 10 parameters for 9 degrees of freedom, implying a hidden constraint. Note also that the analysis takes the laboratory coordinate system as "given" and implies that all other comparable situations can be obtained by an appropriate inhomogeneous Lorentz transformation.

In our bit string model, the algorithm which generates the strings provides the labels with an invariant significance, no matter how long the content ensembles keep on growing in both length and number. This allows us to assign (in ratio to the fundamental mass of the theory) an *invariant* mass m_a (or, equivalently, an invariant step length $h/m_a c$) to label L_a, and so on. Eventually, of course, we are committed to calculating, or approximating these mass ratios self-consistently. Further, if the content string has k_a 1's and $n - k_a$ 0's, then the corresponding velocity is $\beta_a = \frac{2k_a}{n} - 1$. Consequently, all we need to go from the bit string model for a 4-event to the standard Mandelstam description for any particular channel is to find two angles and one constraint. Since $(ab) = (cd)$, in addition to the four external velocities (related to those observed in the laboratory counter telescopes) we have the internal velocities $\beta_{ab} = \beta_{cd}$, providing the constraint. In order to obtain the two angles, we need only use the standard velocity composition law in two dimensions, $\beta_{ab} = f(\beta_a, \beta_b, cos\theta_{ab})$. Then standard 3-momentum conservation and the usual Lorentz-invariant description for the *external* parameters are an algebraic consequence of our bit string model. Remember that our bit strings are generated in the unique *cosmological* frame in which the $2.7^o K$ background radiation is at rest, so that an appropriate transformation must be applied before using any theoretical prediction in a terrestrial laboratory; in most cases this *caveat* can be safely ignored.

What remains to be done is to work out all the quantities of interest in terms of the four external masses and velocities, and one internal velocity for each channel, show that the result is unique, and that the channels are properly related to each other by crossing.

2.2. Discrete quantum numbers

In our kinematic discussion, we ignored the fact that $|k_a - k_b| \leq k_{ab} \leq k_a + k_b$, and hence that $cos\theta_{ab}$ can take on only $2k + 1$ values, where k is the smaller of k_a and k_b. Clearly this implies that each particle can be described by one rational fraction velocity and two angular momentum quantum numbers. One important thing to be done is to show explicitly how these quantum numbers relate to the usual definition of quantized angular momentum, how these quantum numbers transform under Lorentz transformations and finite rotations, and to derive in this representation the usual angular momentum commutation relations. That this has to work out has been proved, in principle, by McGoveran (Ref. 5), but an explicit formal proof in the 4-event context would greatly assist in exposition of the theory and its application to specific problems. Recall also that since $\beta = \frac{2k}{n} - 1 = \frac{2kN}{nN} - 1$, a content string of length nN contains N deBroglie wavelengths specifying the positions where a particle with average velocity β could (but need not) interact. Further, our treatment of the hydrogen atom (Ref.'s 1-3) shows that this definition of periodicity can be extended to the bound state case; in the case of hydrogen $N = 137N_B$, where N_B is Bohr's principal quantum number. Thus, once we have worked out the connection between bit string quantities and quantum numbers, we will be able to start spelling out the connection between bound and scattering states in out theory (Section 2.4). It is important to realize that for long strings, our description is *much richer* than any discretized "orthogonal and complete" set of conventional quantum mechanical single particle states providing the same resolution in angular momentum and linear momentum. We suspect that this richness will, when worked out, make it easier to understand what aspects of "second quantization" our theory contains and where it differs from, for example, Pauli and Brodsky's discretized theory for QED and QCD. Clearly one critical thing to be done is to explore this connection.

2.3. Conservation laws for Labels

Once we have worked out the finite quantum number conservation laws in momentum and configuration space, it will become much easier to see how they work in the finite baryon number, lepton number, charge space in which the labels reside. At this point we may be able to choose from among various explicit representations of the quantum numbers of the standard model which have been suggested the most "natural" one. However, we should be cautious that in doing so we take account of the cosmological issues raised below, and keep enough flexibility to accommodate "dark matter" within the scheme.

2.4. Cross section calculations

One problem with the approach to scattering theory via the "propagator" on which we have implicitly relied in the past, as mentioned at the start of this section, is that it commits us to calculating complex scattering amplitudes and hence to taking their absolute squares to predict cross sections. This does not fit naturally into a theory based on rational fraction velocities and integral quantum numbers such as we have developed above. While some recent work by Karmanov and Stein[10] may show us how to relate real probabilities to complex amplitudes using the random walk model, at present this is but a hope. A related difficulty is that up to now we have talked about "Yukawa vertices" and Feynman diagrams as if they were the same for us as for conventional theory. But conventional 3-vertices carry the coupling constant g, while the natural quantity given by our theory is g^2, as, for example, $e^2/\hbar c = 1/137$ to lowest order. We can finesse this problem up to a point by using only paired vertices clothing a propagator, as is done in the finite particle number scattering theory (Ref. 9), but the amplitude - cross section problem remains. A fundamental way out of the difficulty would be to develop a scattering theory which gives the density matrix directly rather than making the detour through complex amplitudes.

This might prove to be possible. Consider our calculation of the Bohr atom (Refs. 1-3) which combines the internal frequency $1/137N_B$ in quadrature with the *zitterbewegung* frequency coming from the rest mass subject to the bound state constraint to obtain the relativistic Bohr formula

$$(E/\mu c^2)^2[1 + (1/137N_B)^2] = 1$$

Thus we have a *non-perturbative* method for calculating relativistic bound states which can be extended to the next order in $1/137$ to obtain the Sommerfeld formula, and which gives the binding energies (relative to two separated particles) correctly as proportional to e^4 rather than e^2. The fact that to order $1/137$ the corresponding Rutherford scattering can be formulated in terms of the same energies (classical "distance of closest approach") suggests that we might also be able to obtain the Rutherford formula (also proportional to e^4) directly from our theory rather than making a detour through amplitudes. Assuming that we have a correct treatment of Rutherford scattering, the next step would be to decompose it into angular momentum states, and see how they combine to yield the differential cross section. Then the treatment must be extended to non-coulombic scattering and the two in combination. Basically what is to be done here is to develop the full power of the phase shift analysis of cross sections in our own terms, including the effects of the identity of particles.

2.5. Zero mass particles

Up to a point, our bit string states for massive particles are not strikingly different from those in ordinary relativistic quantum mechanics. Our content strings always have a number of 1's (k) which differs from either 0 or n in any Lorentz frame our theory allows us to reach, so the velocities are always less than c. However, our bit string model differs significantly from the standard second quantized field theory description of zero mass "particles" (neutrinos, photons, gravitons).For us these "particles" can have only the content strings $(1)_n$ or $(0)_n$ corresponding to $\pm c$ in *any* coordinate system, and the string does *not* define either an energy or a momentum. Consequently we have to attach such strings to finite mass particle vertices in order to define these quantities. In other words, our theory forces us to adopt a Wheeler-Feynman point of view that all massless "radiation" must be absorbed before we can give precise content to the conservation laws. We cannot discuss 4-events involving massless particles in isolation, but must embed them in a context in which all *external* lines are massive. What is to be done about this is one of the most important unfinished tasks in the theory. It will have to be faced before we can deal adequately with many of the topics discussed in succeeding chapters.

3. PROBLEMS WITH UNIFICATION

Our theory is "born unified". Any bit string can combine with any other bit string at any stage in the evolution of the bit string universe. Our basic problem is to show that the probabilities of these interactions correspond correctly to the "coupling constants" measured in the laboratory. This leads to different problems in different contexts.

3.1. GRAVITATIONAL-ELECTROMAGNETIC UNIFICATION

We have no place in the theory for two different kinds of mass. Thus for us the "equivalence principle" is a deductive consequence and not a postulate. There is no need for us to "geometricize" gravity at this level of the discussion. However, the computed ratio $\frac{e^2}{Gm_p^2} = \frac{2^{127}+136}{137}$ differs from experiment by one part in 218, which gives no obvious clue as to how the next order correction is to be computed. Clearly this is to be done as soon as someone has a good suggestion.

As we have discussed elsewhere[11] our successful treatment of the relativistic bound state problem for hydrogen allows us to extend the treatment to gravitational orbit problems, including the deflection of starlight by the sun and the precession of the perihelion of Mercury. However, our treatment of macroscopic matter in these calculations is still much too heuristic. One thing that needs to be done is to give a more careful treatment of this problem. Further, the deflection of starlight requires us both to use the interaction between gravitation and zero mass quanta and to extend our treatment of Rutherford scattering to the gravitational case.

3.2. Geons and Dark Matter

Our general argument for the existence of dark matter is simply that before level 3 of the hierarchy has been constructed we cannot identify the fine structure constant that defines the coupling to visible matter. Since, statistically, the first two levels will be forming with probability 127/(3 +7) compared to level 3 we anticipate 12.7 times as much of this unfamiliar stuff (which comprises most of the mass of the universe!) as of ordinary matter. However, once the full hierarchy label scheme has developed, we should be able to identify what this dark matter is. Since it has 10 degrees of freedom, one speculation is that it consists of the two chiral neutrino states, the two chiral electromagnetic photons, Newtonian gravitation and the 5 states of the spin 2 gravitons all bound together to make finite mass objects that could be thought of as a quantum version of Wheeler's geons. That we need all six gravitational states and not just the chiral gravitons plus Newtonian gravitation would be for the same reason that we need all six states to account for the precession of the perihelion of Mercury. Clearly, one thing that is to be done is to clean up this argument or to replace it with a better one.

3.3. Weak-Electromagnetic Unification

Although the count of neutrino-electron-photon-weak vector boson states can be made to come out right when we couple them at level 4, we as yet do not have anything like a natural representational scheme, let alone a uniqueness proof. Further the estimate of the Fermi constant $G_F m_p^2 = 1/256^2\sqrt{2}$ relies on the 256 taken from the mapping matrix construction of the combinatorial hierarchy. Since there is no particular reason at present to single out this construction compared to other ways of getting the hierarchy, we need a better justification for this number. The estimate $sin^2\theta_{Weak} = \frac{1}{4}$ comes from noting that the simplest coupling to the Z_0 makes it pseudo-vector like the W; this is not a very strong argument until we can compute the correction and understand why the other parity state also comes in. We really need to understand whether or not we need the Higgs bosons.

Otherwise their "discovery" — to which many millions of dollars are currently committed — could prove to be embarrassing to us. occurs. It may well be that our theory does imply some exotic particle types when we push it this far; whether they should resemble the Higgses is not known to us at present. Cleaning up our position on this frontier question could provide us with the "prediction" we need to convince the skeptics.

4. COSMOLOGY

4.1. Program Universe revisited

Two recent versions of *Program Universe* differ[12] in that one increments ("TICK's") each string by concatenating an individual arbitrary bit whenever discrimination fails to produce a novel string and the other whenever two identical strings are PICKed. As DMcG has pointed out, neither scheme is strictly constructive. We now know that there are many other ways to generate the combinatorial hierarchy, some of which are, presumably, strictly constructive. Once we start asking detailed questions about cosmology, the precise generation scheme adopted for the bit string universe can have directly observable consequences. Thus all questions asked below can react back on the problem of which generation scheme should be adopted.

4.2. The mass scale; Fireball time

Fortunately the answer to the question as to whether to take the unit mass in our theory to be m_p or $M_{Planck} = [2^{127} + 136]^{\frac{1}{2}} m_p$ seems to be independent of what generation scheme we user for the strings. Choosing m_p implies that the universe has a visible mass of about 4.84×10^{52} gm (see Ref. 1), which relative to the "critical" density which would "close" the universe ($\Omega = 1$) gives us $\Omega_{Vis} = 0.01175$ in good agreement with current observations, while the alternative choice implies at least 10^{19} times too much mass!

Once we have made this choice, we have to accept that it takes at least $[2^{127} + 136]^2$ discriminations to generate the labels for matter as we now know it, or 3.5 million years before can talk about space and time and particles in anything like the contemporary sense. We suggest that this is also the "time" when the radiation breaks away from the matter and the universe becomes matter-dominated (fireball time). However, in order to justify this identification, more quantitative work has to be done.

4.3. Baryon number conservation; photons per baryon

As is discussed in Ref. 1, the identification of "fireball time" with which we end the last section assumes that about then the number of photons per baryon is fixed at about 10^9 and that for most cosmological purposes the "here and now" laws of physics are a reliable guide for discussing the next fifteen thousand million years. Yet contemporary cosmological arguments insist that we can go back to the "first three minutes" reliably, and that interesting questions in experimentally accessible elementary particle physics are tightly coupled to what went on at much shorter "early times". It is important to see to what extent our model allows us to discuss this interesting early region, and whether we have a way of calculating the number of "photons per baryon" which emerge from the fireball.

The long time scale used in the last section ignores two aspects of our hierarchical scheme. In the first place, the $2^{127} + 136$ labels needed to give (to 1 %) the current value of $\hbar c/Gm_p^2$ do not exclude much stronger estimates of "gravitation" at "earlier" times. If, as we are required to in our scheme, "gravitation" is characterized by the anti-null label $(1)_L$ which interacts with everything in the same way, its probability of occurence increases as we look back to shorter and shorter labels. It only begins to separate out from the "weak" interaction when there are more that 256^2 labels, and both separate from the "electromagnetic" only when there are substantially more than 137 labels (ignoring all but the first generation of the standard model for quarks and leptons). Consequently if in an evolutionary scheme we take the first three levels of the hierarchy as an adequate first approximation to discuss "matter" in the first generation of quarks and leptons approximation, and everything else as "content" [which will get shifted over into higher generation "label" as the bit string universe evolves], we could begin to start talking about the early evolution of matter somewhere between $(137)^2 h/m_p c^2$ and $(256)^4 h/m_p c^2$, i.e. between 4×10^{-20} and 10^{-13} seconds. Since the critical number of particles compared to massless quanta in this era could well be something like $1/256^2$, the fluctuation that gives us baryons rather than anti-baryons could well turn out to be of the order of one part in 10^9. Once again carrying through this calculation is one thing that is to be done.

4.4. Galactic and meta-galactic structure

If we can get this part of the early cosmology right in our "basically flat" model, and see how this relates to the formation of "dark matter", we might anticipate the formation of at most 16 hierarchical levels of galactic and meta-galactic gravitational structures as we evolve on up to fireball time. Do it!

4.5. Deuteronomy

This term used for the formation of deuterons, the most critical current indicators of complex matter surviving the first 15 minutes and subsequent stellar evolution, and implying the other light element cosmic abundances as well, has a nice cosmological resonance to it. Cosmologists using continuum models for this early stage in the evolution of the universe think they are on firm enough ground at this time horizon to make quite detailed statements about which speculative models can be ruled out and which survive based on current observations of "cosmic abundances". We need a firmer handle on both our nuclear physics and on our version of *program universe* before we can have as much confidence. One thing that need to be done is to provide a solid basis for comparable confidence in our own terms.

5. QUANTUM ELECTRODYNAMICS; QCD

5.1. Sommerfeld formula finite mass correction

Since the action needed with respect to extending the Sommerfeld formula to include finite masses is discussed in the Appendix, we ignore that problem here. However, as we go to press, we have just received a note from Larry Biedenharn enclosing a careful discussion[13] of why the fact that both Sommerfeld and Dirac ended up with the same fine structure formula is *not* an accident. Among other things this involves the question of "spin" in a profound way. Since we had already realized that the question of spin is also implicated in how the finite mass correction comes about, one thing that needs to be done is to relate Biedenharn's analysis to our combinatorial calculation.

5.2. Positronium

The triplet decay of positronium calculated to order α^2 gives a term about ten times that "expansion parameter" rather than (as in most QED calculations something like, eg $1/\pi$ time the expansion parameter. The α^3 terms have not been calculated, but the experiments indicate they would have to be something like a hundred times the expansion parameter in order to agree with experiment[14]. This looks promising for us, since we have in hand a *non-perturbative* method for calculating relativistic bound states.

5.3. Lamb shift, etc.

Once we have α^2 QED in hand, we should go on to the next order effects. Not only do we have non-perturbative bound state calculations to start from but we are guaranteed from the outset that our results have to be finite. This is the place to either kill our theory, show where it has to be modified, or reinforce the growing conviction that it goes much deeper into the structure of the universe than our opponents are likely to concede.

5.4. Pion masses and lifetimes

Both the gravitational problems discussed in earlier sections and the QED questions raised in this section, if successfully met, would make it very likely that we can model the neutral pion as 137 electron-positron pairs, as was suggested long ago.[15] If this works, and we have the weak-electromagnetic unification in hand, we should be able to add an electron and a neutrino to the model to get the charged pions as well. The proof of the pudding will be not just the correct binding energies but also the correct lifetimes. This must be done.

5.5. QUANTUM CHROMODYNAMICS

A number of topics in strong interaction physics are crying out for treatment with tender, loving care. To begin with, by forming the color singlet states at level 3 we should have a good phenomenology for low energy nuclear physics, in which the non-perturbative aspect of our calculations for relativistic particulate systems should come into its own. Once we understand these "boundary states" for quark-gluon systems, we will have a fighting chance to tackle both the question of running quark and gluon masses, and the problem of how quarks "hardonize" following high energy parton collisions. Both problems are at the frontier of current research in quantum chromodynamics. Going beyond the first generation of quarks and leptons poses a well defined statistical problem for us. In principle we should have little difficulty calculating the Kobyashi-Maskawa mixing angles once we have settled on an explicit label scheme for quarks and leptons. We have much less freedom that conventional attacks on the "generation puzzle." This gives us an important opportunity for a new prediction, but also renders us quite vulnerable if it does not come out right. At the same time we must be able to understand CP non-conservation arising in the third generation, and why for us baryon number conservation has a different origin.

6. CONCLUSION

Once we have thrown off the chains of illusion which shackle most physicists to the continuum, we have an incredibly rich world to explore and conquer.

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Appendix

McGoveran and Noyes, "On the Fine Structure Spectrum of Hydrogen"

Referee comment:

"I recommend that this letter be rejected. How happy we should all be to publish a physical theory of the fine structure constant! Any such theory, right or wrong, would be worth publishing. But this letter does not contain a theory which might be proved right or wrong. The formula for the fine-structure constant comes out of a verbal discussion which seems to make up its own rules as it goes along. Somewhere underlying the discussion is a random process, but the process is never precisely defined, and its connection with observed quantities is not explained. I see no way by which the argument of this letter could be proved wrong. Hence I conclude that the argument is not science."

Suggested response:

We agree completely with the referee that if an argument cannot be proved wrong, it is not science. Since he grants us that any theory of the fine structure constant "... right or wrong, would be worth publishing" we assume that if we can convince him that our theory is refutable, he will recommend publication. Before we rewrite the paper with this in mind, we first spell out our line of argument so that we can learn from him in what ways he would like to see the paper modified in order to meet his primary objection.

One very clear way in which the theory we present could be proved wrong is if it could be shown that it does not allow us to calculate correctly the finite mass modification for the Sommerfeld formula. As is well known, simply using the non-relativistic value for the system mass $\mu = \frac{m_1 m_2}{m_1+m_2}$ — which suffices in the Bohr atom — no longer works. To the α^2 order in which we are working the modified expression is usually assumed :[16-18] to be given by:

$$S_n = m_1^2 + m_2^2 + \frac{2m_1 m_2}{[1 + Z^2\alpha^2/(n-\epsilon_j)^2]^{\frac{1}{2}}}$$

where

$$\epsilon_j = j + \frac{1}{2} - \sqrt{(j+\frac{1}{2})^2 - Z^2\alpha^2}$$

and j is the total angular momentum for the Dirac case, or the orbital angular momentum (ℓ) for the spinless (Klein-Gordon) case.

This formula is in agreement with experiment for hydrogen, positronium and muonium to this order in α, but we are not aware of any spin 1/2 - spin 0 or spin 0 - spin zero *elementary particle* systems where it has been tested to appropriate accuracy. We are looking into this experimental question. This raises two problems for us, first to get the mass terms in the formula and second to get the spin dependence. That we can expect the masses to add in quadrature follows from the same argument we use about frequencies adding in quadrature in the original paper, but the spin terms are another matter. The argument in the paper as it stands gets the α^2 in the Sommerfeld formula only by assuming the system contains two spin 1/2 particles, so we could be in trouble if we find that to this order we are required to use different values for α^2 in different spin states. If we are, then there will be a clean experimental test between our theory and conventional QED, which will be worth pursuing. If not, then we will have to look to other α^2 or higher order effects. Eventually, of course, we have to carry thorough our calculations up to the level where QED is tested, which cannot be done in a year or two. One obvious place to look is in the triplet decay of positronium, and this problem is on our agenda.

As to the arbitrariness in our rules, on which the referee also comments, he probably does so without having perused "An Essay Discrete Foundations for Physics"[19] in which our methodology is explained in more detail. This paper will appear shortly in *Physics Essays* (galley proof has been corrected and the issue is in press); we supplied the Editor with a preliminary version because it would not otherwise be available to the referee. For his use we supply a preprint of the revised version that is essentially what will be published. To emphasize the scope of the work, we append a sheet entitled "Summary of **WHERE WE ARE**". These items can be thought of as our "first order" results. The calculation of α at issue here is our first "second order" result; we thought it sufficiently striking to justify publication in *Physical Review Letters.* Since we have identified the limiting velocity, Planck's constant and the unit of mass in the theory, we are under the obligation eventually to get *all* of these numbers to agree with experiment within the prior estimates of the accuracy we can expect at the level of calculation achieved. For instance our calculation of the ratio of the gravitational to the electromagnetic interactions is out by about 1 %. Now that we have shown how to make a second order calculation of α, we are required to see if we can compute this correction as well. We anticipate an "electromagnetic-gravitational unification" correction of order α, but if it can be show that this has to go in the wrong direction, this in itself would kill our theory, at least in its current form. Our standards are in fact *much stricter* in this sense than for more conventional "theories of everything".

With this understood, we return to whether we are "making up our rules as we go along". In a sense, of course we are, as does any other group of theorists creating a new theory. For instance, the initial claim that QED was renormalizable to all orders in perturbation theory turned out to be fallacious until Matthews and Salam had removed an important ambiguity. The extension of QED to other "matter fields" and the choice of the symmetry groups to be used was led by experiment and in no sense dictated by theory until an enormous body of empirical material had been collated. HPN still remembers the heroic struggles decades ago to "prove" that second quantized field theory could be given a rigorous axiomatic foundation. Eventually these were abandoned.

As we have said elsewhere (Ref. 4, p. 68 in enclosed preprint)

"It is sometimes suggested that ours is a "Pythagorean" or *a priori* theory. This criticism implies a lack of understanding of our modeling methodology. We *start* from the current practice of physics, both theoretical and experimental, and try to construct (a) a self-consistent formal structure guided by that prior knowledge and (b) rules of correspondence that bring us back to laboratory practice, including empirical tests. In this sense, we are trodding a well worn path followed by many physicists engaged in constructing fundamental theories."

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Summary of **WHERE WE ARE**

General structural results

- 3+1 asymptotic space-time
- transport (exponentiation) operator
- combinatorial construction of π
- limiting velocity
- supraluminal synchronization and correlation *without* supraluminal signaling
- discrete events
- 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

Gravitation and Cosmology

- the equivalence principle
- 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= 12.7 times visible matter [10??]

Unified theory of elementary particles

- quantum numbers of the standard model for quarks and leptons
- gravitation: $\hbar c / G m_p^2 = 2^{127} + 136 = 1.70147... \times 10^{38}$ $[1.6937(10) \times 10^{38}]$
- weak-electromagnetic unification:
  $G_F m_p^2 = 1/[256^2 \sqrt{2} m_p^2] = 1.07896 \times 10^{-5} m_p^{-2}$ $[1.02684(2) \times 10^{-5}]$;
  $sin^2\theta_{Weak} = 0.25$ $[0.0229(4)]$
- the quark-lepton generation structure
- generations weakly coupled with rapidly diminishing strength
- color confinement — quark and gluon masses not directly observable
- $m_{u,d}(0) = \frac{1}{3} m_p$
- the hydrogen atom: $(E/\mu c^2)^2 [1 + (1/137 N_B)^2] = 1$
- 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 \times 127}} = 137.0359674...$$[137.035963(15)]$
- $m_p/m_e = \frac{137\pi}{\frac{3}{14}\left(1+\frac{2}{7}+\frac{4}{49}\right)\frac{4}{5}} = 1836.151497...$ $[1836.152701(100)]$
- $m_\pi \leq 274 m_e$: $[m_{\pi^\pm} = 273.13 m_e,\ m_{\pi^0} = 264.10 m_e]$