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ANTI-GRAVITY: the key to 21^{st} Century Physics*

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Abstract

The masses, coupling constants and cosmological parameters obtained using our *discrete* and *combinatorial physics* based on *discrimination* between *bit-strings* indicate that we can achieve the unification of quantum mechanics with relativity which had become the goal of twentieth century physics. To broaden our case we show that limitations on measurement of the position and velocity of an individual massive particle observedin a colliding beam scattering experiment imply real, rational commutation relations between position and velocity. Prior to this limit being pushed down to quantum effects, the lower bound is set by the available technology, but is otherwise *scale invariant.* Replacing force by force per unit mass and force per unit charge allows us to take over the Feynman-Dyson proof of the Maxwell Equations and extend it to weak gravity. The crossing symmetry of the individual scattering processes when one or more particles are replaced by anti-particles predicts both Coulomb attraction (for charged particles) *and* a Newtonian repulsion between any particle and its anti-particle. Previous quantum results remain intact, and predict the expected relativistic fine structure and spin dependencies. Experimental confirmation of this anti-gravity prediction would inaugurate the physics of the twenty-first century.

1. WE NEED A NEW STRATEGY

The ANPA program has achieved a number of quantitative successes in calculating most of the fundamental mass ratios, coupling constants, and cosmological parameters needed in elementary particle physics and physical cosmology. These are summarized in the Table which concludes this paper. One might think that this success, which conventional "theories of everything" are aiming at, but have no more than vague ideas as to how to accomplish quantitatively, would provoke some interest among physicists and cosmologists. Yet when I finally succeeded in getting a short announcement published in the magazine that goes to all US Physicists,[1] I only got *one* enquiry — a brief "What the hell is going on?"! I replied with technical details, but got no response. I have also tried to involve several elder statesman of my acquaintance, but among the theorists have garnered little interest.

The stock response is "Predict something that hasn't been observed." Of course no other theorist is doing that in our sense. They usually take a generous amount of both structure and parameters from existing experiments and attempt to compute a correction or two that might be observable. To play that game, we have to analyse nearly half a century of theoretical and experimental work by thousands of the best physicists in the world and recast it in our own terms. I am making progress along these lines, but without the help of eager and conventionally trained colleagues, cannot hope for any rapid developments. Even the top quark mass is getting pinned down; this is the last well defined parameter that could be predicted prior to experimental observation. Improvement on the values of the Kobiyashi-Maskawa mixing angles will get us little recognition. There are enough theories of neutrino masses around to insure that one of ours would be bound to have a successful conventional alternative. About all we can do is make the negative prediction that there should be no Higgs mesons with simple structure. However, we can expect many of the effects which will be used to "discover" Higgses are also contained in our theory. A clean discrimination between our theory and conventional alternatives will take even more work than getting the K-M parameters right, and will require many of the same steps.

Of course some members of the ANPA community resist the idea that we are trying to construct a new physical theory to be evaluated using the same criteria as those employed by the establishment. But, at least to the jaundiced eye of this physicist, I see no evidence that conceptual clarity and philosophical purity will do us much good. Many mathematicians and computer scientists claim just that, and I see no likelihood that we will stand out among the host of competitors. Physicists pay no attention to that vast body of literature in any case. Those of us who want to convince *physicists* that the ANPA program has led to exciting new results will have to find a new strategy.

Fortunately, experimental high energy physicists are more willing than the theorists to entertain new ideas. They are properly distrustful of theorists, and unhappy with an experimental situation that relies so heavily on intricate theoretical calculations to "measure" *anything.* Maurice Goldhaber was intrigued with the idea that anti-matter might fall up, and suggested looking into tests with muonium and anti-muonium. Direct free fall tests are impossible because of the 2.2 microsecond lifetime. But he is looking into another possibility, which — so far — he is keeping close to his chest. The experimental groups working with anti-protons and trying to produce anti-hydrogen atoms have a lively interest in the prediction that anti-protons will fall up which Starson and I made at ANPA WEST 7.[2] I have recently reviewed their experimental programs.[3]

Making a case for anti-gravity has provoked more interest in the ANPA program among physicists than anything else to date. I propose to follow it up vigorously. I believe that even if the prediction fails, we will get more constructive attention from that failure than from any improvement in our quantitative predictions, no matter how impressive. But even within ANPA, I have failed to elicit any attempts to improve on or to refute my arguments for anti-gravity. I hope that this paper will stimulate or provoke some constructive criticism.

2. BOHR-ROSENFELD REVISITED

Bohr and Rosenfeld[4,5] proved that the restrictions on measurability due to the *non-relativistic* uncertainty principle applied to the charges and currents which detect the fields can be used to *derive* the commutation relations between the electric field E and the magnetic field H which are more easily obtained by the legemanderain of "second quantization". Basically, this is possible because the theory involves only h and c, leaving it *scale invariant.* This allowed them to use as complicated an apparatus as they liked *within* a wavelength of the radiation. Their apparatus consisting of rigid rods and springs, massive charged objects and current loops. The rods and springs are used to compensate, in so far as possible, for radiation reaction, and can get pretty complicated. One post-doc who reviewed the paper at a SLAC seminar called it an exercise in nineteenth century electrical and mechanical engineering!

In the course of preparing the final version of my paper for PIRT III,[6] I came to realize that the non-commutativity of position and momentum measurements made using macroscopic counters can be cast in a scale-invariant form by making angular momentum per unit mass (area change per unit time) the basis of quantization rather than angular momentum. Then the units of quantization of length and time and the measurement of mass ratios depend only on space-time measurements. For instance they can be related to the smallest measured velocity in units of c, and a scale invariant quantity set by technological assumptions. Thus the basis for the Bohr-Rosenfeld argument can be recast *without* introducing Planck's constant provided only that the sources and sinks of the field are relativistic charged particles. This removes the restriction of their paper to non-relativistic quantum mechanics, which is obviously desirable.

Once one has scale invariant commutation relations between position, velocity and angular momentum per unit mass, the very peculiar proof of Maxwell's Equations which Feynman showed to Dyson in October, 1948 but refused to publish during his lifetime[7] becomes understandable. I had argued elsewhere that this derivation is rigorous within the framework of bit-string physics.[8,9] The new derivation presented here is scale invariant, making the proof even more general. It therefore seems worth while to present this new result before discussing the gravitational field.

3. PROOF OF THE MAXWELL EQUATIONS

The Feynman-Dyson proof of the Maxwell Equations starts with Newton's Second Law

$$m\ddot{x}_j = F_j(x, \dot{x}, t); \; j \in 1,2,3 \qquad D-1$$

and the commutation relations

$$[x_j, x_k] = 0 \qquad D-2$$

$$[x_j, \dot{x}_k] = i\hbar\delta_{jk} \qquad D-3$$

and proves that there exist fields $E(x,t)$ and $H(x,t)$ satisfying the Lorentz force equation

$$F_j = E_j + \epsilon_{jkl}\dot{x}_k H_l \qquad D-4$$

and the Maxwell Equations

$$div\ H = 0 \qquad D-5$$

$$\frac{\partial H}{\partial t} + curl\ E = 0 \qquad D-6$$

The proof relies on the Jacobi identities and taking a total derivative with respect to time, but involves no formal subtleties.

Because our theory is relativistic, we measure all speeds in units of c. Since, by definition, $c = 299\ 792\ 458\ m\ sec^{-1}$ we can always pick our dimensional scales in such a way that these speeds for any massive particle in any one direction are rational fractions less than unity.

Our first step is to eliminate the concept of mass from the problem in favor of mass ratios measured relative to some standard particle beam using only space, time, velocity and velocity change measurements. For this purpose we use *counter telescopes* consisting of two *counters* with thickness Δl containing recording clocks having the time between ticks Δt. We pick our units such that $\Delta l = c\Delta t = 1$, making all measurable distances and times *integers.* This commits us to insuring that we never talk about fractional space and time intervals as *measurable.* If the spacial interval between the counters is L and the time interval between two sequential counter firings is T we attribute the counter firings to the passage of a particle with velocity $V = L/T$. All data discussed here will be collected at a slow enough rates so that the interval between the passage of particles allows this measurement to be unambiguous. We also assume that, to an accuracy to be discussed, all four of the telescopes introduced below (eight counters) record the *same* speed.

Although, by hypothesis, $V = L/T$ must be a rational fraction less than unity, we will not in general be able to measure L and/or T to the nearest integer. To represent this fact we define

$$v = \frac{t_1' - t_1}{t_1' + t_1} = V = \frac{L}{T}; \quad L = N(t_1' - t_1); \quad T = N(t_1' + t_1) \tag{3.1}$$

We assume that t_1' and t_1 *are* known to the nearest integer and that N can be estimated but not directly measured. By interference techniques we do not have time to discuss in this paper, one can measure relative path lengths and determine N to the nearest integer. What remains unobservable is the time t in any interval $0 \leq t = n_t\Delta t \leq t_1 + t_1'$. In this finite and discrete language, we are talking about a periodic phenomenon with N periods, each of duration $\mathcal{T}(v) = t_1 + t_1'$ whose *absolute* phase is unknown within a period. The fraction $t/\mathcal{T} < 1$ is our conceptual equivalent of the unobservable phase of quantum mechanics in a *scale invariant* context bounded from below by measurement accuracy rather than something related to Planck's constant.

Our paradigm for position and velocity measurement is to use four counter telescopes 11',22',33', 44' all pointed at the same region. To a first approximation, the lines 11',etc. all pass through a "circle of confusion" X of radius unity. We assume that the first two counter telescopes fire in the sequence 11'22' and the second pair in the sequence 33'44', and that 1'23'4 lie on a circle of radius d centered at X. We assume that the lines 1'2 of length b and 3'4 of length b' are parallel and are bisected by a line perpendicular to them through X. That is we have two isosceles triangles with a common vertex and parallel bases. Calling their inferred heights h, h' and angles $\pi - \theta$, $\pi - \theta'$we have, as a first approximation,

$$h^2 = d^2 - \frac{1}{4}b^2 = 2d^2 sin^2\frac{\theta}{2} = h^2[(\frac{d}{b})^2 - \frac{1}{4}] \tag{3.2}$$

and similarly for h', θ'. We take as our coordinate directions j parallel to the altitudes h, h' and k parallel to the bases b, b', and assign coordinates (x_j, x_k) as follows:

$$1' : (0,0); \quad X : (h, b/2); \quad 2 : (0, b) \tag{3.3}$$

We now relate this geometry to the common velocity v registered by all four counter telescopes and the fact that we can only measure times to an accuracy $\Delta T = t_1 + t'_1$. Then

$$1'X = X2 = d = 2v\Delta T; \quad 1'2 = b = (\frac{b}{d})2v\Delta T \tag{3.4}$$

and the velocity components are

$$v_j^{1'\to X} = (\frac{h}{d})v; \quad v_j^{X\to 2} = -(\frac{h}{d})v; \quad v_k^{1'2} = (\frac{b}{2d})v; \quad v_j^2 + v_k^2 = v^2 \tag{3.5}$$

In order to make this into a scattering experiment, we assume that each time we get the sequence of firings 11'22' we also get the sequence of firings 33'44'. For sufficiently weak beams, this will be unambiguous. We attribute this confluence of events to the scattering of one particle from each beam within the region X. We can then *define* the ratio of the mass m' of the particles in the second beam to the mass m of the particles in the first beam by the equality

$$m'b' = mb \tag{3.6}$$

It is a matter of experience that the *scale invariant* equality $m'/m = b/b'$ is independent of the commom measured velocity v for all known pairs of particles which can be compared in this way and hence defines a velocity invariant scale for all particles relative to any one type. Note that we make the comparison at the *same velocity* to avoid the complications of relativistic kinematics. This is why our theory can remove the puzzle stressed by Dyson that the Feynman derivation seems to produce peaceful coexistence between Newtonian and non-relativistic quantum mechanics and the Lorentx invariant Maxwell equations they seem toimply.

This step allows us to replace forces — which historically related masses compared inertially to masses compared using weight — by mass ratios using the relativistic equivalent of Newton's Third Law, a step we freely acknowledge was suggested to us by Mach in his *Science of Mechanics.* The advantage of using this macroscopic and operational *change* in the velocity $2v\ sin^2\frac{\theta}{2}$ is that we can measure both the magnitude v and the scattering angle θ using macroscopic counter telescopes. Although we have described this situation as if the particles met at a point, all we can measure macroscopically are the scattering angles θ, θ' and the common rational fraction velocity to some finite accuracy. Thus, the "interaction" could well be *non-local.* As we have shown elsewhere,[10] this description is invariant under appropriate rational velocity boosts and finite angular rotations. We claim this is the appropriate starting point for a *scale invariant relativistic action at a distance* theory. Comparison of the different mass beams at the *same* speed allows us to defer discussion of relativistic kinematics to a later point in the development.

We can now start the proof, replacing Dyson's F_j by $f_j \equiv \frac{F_j}{m}$. We use a common time interval ΔT to measure all velocities $\dot{x}_i \equiv v_i$ and all velocity changes

Δv_j (rather than discussing accelerations $\ddot{x}_j$). Then Newton's Second Law, (D-1), becomes

$$f_j = \Delta v_j \qquad N-1$$

Because the eight counters occupy fixed positions, the coordinate $x_k = b/2$ of the midpoint between 1' and 2 and between 3' and 4 can be chosen independent of how we decide to interpret the measurement of position and velocity "at" X. Therefore Dyson's postulate (D-2) holds for us as well.

Our next step is to view this impulsive velocity change as a *measurement* of position x_j and velocity v_j of the particle in the first beam, to the limited accuracy allowed by the "circle of confusion" around X produced by our assumption that we cannot give meaning to distances less than Δl and times less than Δt. We have defined our units so that this is a circle of radius 1, until we fix the x_k coordinate by (D-2). Then it becomes a line segment of length one between two coordinates $x_j^{1'} = h_1$ and $x_j^2 = h_2$. The lines from either h_1 or h_2 to either counter will have lengths

$$d_1^2 = h_1^2 + b^2/4;\ d_2^2 = h_2^2 + b^2/4 \qquad (3.7)$$

If d_1 runs from 1' to h_1, the velocity

$$v_j^{1' \to h_1} = +(\frac{h_1}{d_1})v \qquad (3.8)$$

which differs from the v_j in 3.5 by $[(h_1/d_1) - (h/d)]v$. Since our measurement philosophy does not allow us to assign the momentum change to a point, the line d_2 must then run from h_2 to 2 and the corresponding velocity component is

$$v_j^{h_2 \to 2} = -(\frac{h_2}{d_2})v \qquad (3.9)$$

which differs from the v_j in 3.5 by $[(h/d) - (h_2/d_2)]v$. We can now attribute the position measurement to position h_1 followed by a velocity measurement at position

h_2, i.e. $x_j = h_1$, $|v_j| = (h_2/d_2)v$, or in the opposite order, i.e. $|v_j| = (h_1/d_1)v$, $x_j = h_2$. Hence $[x_j, v_j] = \frac{h_1 h_2 (d_1 - d_2) v}{d_1 d_2} \neq 0$ It is of little interest what this constant is. All we need in this paper is that we can replace Dyson's (D-3) by

$$[x_j, v_j] = C\delta_{jk} \qquad N-3$$

where C is fixed by the accuracy achieved or postulated in the technology of scattering measurements. Examining the remaining steps in the Dyson proof, we find that they only require the commutator to be a *constant* independent of x_j, v_j, and *not* on this constant being imaginary. Therefore N-3 is a satisfactory replacement for D-3 and removes Planck's constant from the problem altogether, provided only we do not encounter explicit quantum phenomena, such as the quantization of radiation independent of measurement accuracy below some threshold.

Equation D-4, interpreted as the force on a particle of charge e is a force per unit charge rather than a force per unit mass. But as used to be well known, using only macroscopic measurements of particle trajectories with static electric and magnetic fields gives us only e/m and not e or m separately. So, once again we can make a scale invariant choice of units such that F_j in (D-4) is the same as f_j in (N-1), leaving us with

$$f_j = E_j + \epsilon_{jkl} v_k H_l \qquad N-4$$

We now have in hand all the ingredients necessary to carry through steps (D-9) to (D-21), the final step in the Dyson proof, which has now become fully algebraic. The algebra is uninformative and will not be reproduced here. The only subtlety is the interpretation of total and partial derivatives as discrete differences along the lines of our derivation of the free particle Dirac equation. We will return to this problem on another occasion. One significant fact about the algebra used in the proof is that it no where makes use of the imaginary equation $i^2 = -1$. McGoveran has remarked that the "i" in quantum mechanics a "book keeping device" of no deep significance. We have provided here a specific example of how this observation can be illustrated.

4. QUANTIZED CONIC SECTIONS

Our approach to the Bohr-Sommerfeld problem[11] starts from our basic postulate that events can, but need not, occur only when they are an integral number of deBroglie wave lengths apart. We can then approximate circular orbits by an integral number of straight line segments representing velocities $\beta_n = 1/137n$ and the closure constraint $2\pi r = j\lambda$

In that approach, we take double slit interference as primitive rather than macroscopic velocity change. If a beam of particles of some velocity v is incident on a slit with spacing w followed by a detector screen a distance D downstream and the spacing between interference fringes on the screen is s, the deBroglie wavelength λ is given in terms of laboratory length standards by the relation

$$\lambda = \frac{ws}{D} \tag{4.1}$$

Then if a beam of particles with a different mass m' but the *same* velocity v is incident on the same arrangement and produces a fringe spacing s', we can *define* the mass ratio by

$$m's' = ms \tag{4.2}$$

The similarity to Eq. 3.6 should be transparent. In discrete physics we think of 3.6 (Newton's Third Law) as *derived* from our quantum mechanical relation 4.2. The advantage of using 3.6 as basic is that we can then treat the classical theory as possessing non-commutativity, but in a scale invariant way down to the point where an *absolute* measurement of $\hbar$ or e has been made.

Once we have recognized that λ, in an appropriate context, continues to represent the minimal measurable distance between distinct events our "scale invariant" treatment of scattering limited by accuracy of measurement can be applied to any macroscopic problem which is on a scale such that Planck's constant does not need to enter the analysis. Our analysis then provides a "correspondence limit" for *relativistic* quantum mechanics in all such cases. In particular, we claim to have proved in the last chapter that Maxwell's Equations can be reinterpreted as a *necessary* consequence of any relativistic action at a distance theory which is careful to incorporate macroscopic limits on measurement, and hence *also* as the correspondence limit of our relativistic particle theory.

Since the primary focus of this paper is on gravitation in the macroscopic limit, our primary interest is in elliptical and hyperbolic orbits rather than in radiation. We will return to quantum effects in Chapter 7, but here need only the connection between Rutherford scattering analysed classically, the analagous problem for gravitating objects, and the relationship between hyperbolic and bound orbits. At the level of analysis we need to establish anti-gravity we can ignore both the gravitational "fine structure" splitting and the loss of energy due to radiation. Then the Coulomb problem differs from gravitation only in that (a) the coupling constant is much weaker and (b) there is currently no empirical evidence for anti-gravity (i.e. hyperbolic orbits corresponding to short range repulsion).

Since I spent some time at ANPA 13[12] discussing the relationship between Galileo's pendulum experiment, Newton's circular orbit paradigm, circular velocities indistinguishable from c (black holes) and our quantum theory, I will defer a detailed "scale invariant" treatment along the lines sketched above to another occasion. I simply note that if we take r_1 as the perihelion distance, $|r_1 - r_2|$ as the distance between foci and $\beta = (k_1 - k_2)/(k_1 + k_2)$ as the velocity at perihelion, we can construct a quantized theory of "conic sections" in terms of three of the four integers r_i, k_i. We then specify the fourth in terms of a macroscopic scale parameter such as the maximum path length of the periodic bound state orbits we use to establish our time resolution, or the maximum size of the scattering chamber we use to measure scattering angles. This in turn can be used to specify the accuracy in the ratio of asymptotic to perihelion velocities we can measure.

5. CROSSING SYMMETRY PREDICTS ANTIGRAVITY

In our discussion of the Maxwell Equations, we made use of a scattering chamber with two entrance and two exit counter telescopes for two particle beams of different mass. This gives us eight counter firings and four velocities determined by space-time measurements. If all four particles are charged, and we back these up by measurements of the radius of curvature in a magnetic field backed up by a third counter to insure that the same $v$is still valid we end up with 16 pieces of information, and can use these to form four energy-momentum 4-vectors which are conservedpairwise between the initial and the final states. These allow us to define our discrete version of the usual Mandelstam variables[13]. Then *any* 2-2 scattering process which can be reduced to a finite number of convergent Feynman diagrams can be calculated for our discrete variables, which have the limits of measurement already built in. Details will be presented elsewhere.

One important fact about 2-2 Feynman diagrams expressed in terms of relativistically invariant variables and quantum numbers is that they are *crossing symmetric.* Suppose we have a diagram that represents a process in which a particle of mass m_1, energy E_1, momentum P_1, angular momentum J_1, and some collection of discrete quantum numbers Q_1 interacts with particle 2 similarly described to produce two particles 3 and 4 similarly described. Crossing symmetry asserts that, where the free particle kinematics of the initial and final free particle states allow, the same diagram with one, two, three or four particles changed to anti-particles represents a physical process whose probability amplitude can be computed from the same diagram in that appropriate kinematic region.

In our bit-string theory, this crossing symmetry derives from the fact that, if we make the proper identification between quantum numbers and kinematic variables derived from bit-strings, interchanging 0's and 1's in a bit-string corresponds to interchanging particle and antiparticle. In particular, this is true of our representation of the standard model of quarks and leptons using strings of 16 bits, although the published demonstrations of this statement are incomplete. If we interchange the 0's and 1's in *all* the strings for a theory in which the combinatorial hierarchy construction has closed, we produce a dual theory which is formally distinct but which is indistinguishable so far as *all* physical predictions go. I have called this Amson invariance. In conventional theories this is the CPT theorem: changing all particles to anti-particles, reversing their velocities ($P_i \rightarrow -P_i$), and making a mirror reflection across three perpendicular planes ($J_i \rightarrow -J_i$) can have no observable consequences. In particular, this theorem requires particles and anti-particles to have identical *inertial* masses. But in the absence of an accepted theory of quantum gravity, gravitational mass (or better "gravitational charge") could either reverse or stay the same.

It is important to realize that crossing symmetry is more restrictive than CPT invariance. For instance, since we know that protons fall toward the earth, all it says that anti-protons fall toward an anti-earth. This is not helpful for constructing an *experiment crusis*! But crossing symmetry applied to the coulomb problem tells us that anti-particles have opposite electric charge to particles and hence that if a particle is attracted toward a center, an anti-particle will be repelled by it. This follows immediately from the conic section formalism we have developed. But for gravitation, the definition of inertial mass remains the same as for coulomb attraction, and the same crossing symmetry applies. Hence, since particles are known to attract each other gravitationally, a particle and its anti-particle should repel each other. *Our prediction of anti-gravity is that simple.* It remains to try to meet objections.

6. THE CONVENTIONAL WISDOM*

To begin with, our prediction is in flat contradiction with the equivalence principle (i.e. that there is no way to detect a difference between gravitational and inertial mass) and hence with General Relativity. For many physicists this is already sufficient reason to dismiss anti-gravity out of hand. Only particle theorists and others who believe in CPT invariance will pursue the matter further. But the usual context in which CPT invariance arises is in the second quantized relativistic field theory. In such theories the electromagnetic field has massless quanta with spin 1 while gravitation has massless quanta with spin 2. There is a general argument that, although the force between two particles which exchange spin 1 quanta is repulsive between a pair of particles or a pair of anti-particles, and attractive between a particle antiparticle pair, it is always attractive between *any* two systems which exchange spin 2 quanta.

However, if one looks at the "proof" of this theorem in more detail, one finds that it does not just depend on the spin of the quanta.[14] In the case of any pair of particles which interact by exchanging massless quanta with integral spin j (in our case j=1 or 2) the momentum change p (or force) must vanish like p^j as p goes to zero. This would be a disaster for the conventional theories, because the major effect observed for small p in electromagnetism is the Coulomb or electrostatic force between charges. For gravitation the only directly measured force is ordinary Newtonian gravity. The spin-2 "gravitons" which the theory predicts cannot be directly detected, and whether classical gravitational radiation has been detected or not is controversial. The way conventional theory gets around this disaster is to insist that the theory be gauge invariant as well as Lorentz invariant. The low momentum limit— if one believes the somewhat tricky mathematics — then produces the desired Coulombic and Newtonian forces out of this theorists hat. But, unlike fields which have a direct connection with the observed motions of test particles, "potentials" whether "gauge" or other, have no directly observable

* **Quoted from Ref 3, with some modifications.**

consequences. One is permitted to view them as theoretical inventions, rather than as a transcription of empirical fact into mathematics. I made the technical argument at the Münich Workshop on anti-hydrogen in April, 1992.[15]

The end conclusion is that *if* anti-protons "fall" up, one will have to abandon *both* the equivalence principle (i.e. gravitational mass is identical to inertial mass) *and* relativistic gauge invariance. Such an experimental result would kill two theories with one measurement, which is a good investment when one is looking for a crucial experiment. Fortunately experimentalists are not deterred by theoretical arguments, and are forging ahead as carefully as they can. We may have the answer in five years.

7. QUANTUM CONSIDERATIONS

Until the last chapter we could ignore "spin" because our fine structure comes from our relativistic analysis of the limitations of measurement and does not depend on the existence of an indivisible unit for orbital angular momentum. Historically it was Bohr's quantization of angular momentum via the quantization of energy that gave a first version of quantum mechanics. His relativistic treatment was an after thought, and Sommerfeld's successful extension did not require the concept of spin.

Our relativistic treatment of Kepler's Laws shows that we can define an impact parameter from the relation $2\pi r = j\lambda = jh/p$ and that if we define $j = r/\lambda$, we have that the square of the area swept out in the time it takes to move λ is $\Delta A^2 = \lambda^4(j^2 - \frac{1}{4})$. Geometrical examination of the alternatives $\ell = j \pm \frac{1}{2}$ shows that they correspond to the straight line of length λ being taken as the tangent or the chord, respectively, showing that $(\Delta A/\lambda^2)^2 = \ell(\ell+1)$ gives the quantum mechanical result (i.e. "ℓ^2" $\rightarrow \ell(\ell+1)$ for the square of the orbital angular momentum ℓ because we are taking the geometric mean between the distinct values computed from the inscribed and circumscribed polygon. This is consistent, because the maximum linear distance between them is h/mc. If we tried to measure this difference to the accuracy of $\pm h/2mc$, we would be able to create a particle anti-particle pair, and would have to include their degrees of freedom in the analysis before we could proceed.

The same analysis shows that a transition between the two possibilities changes ℓ by $\hbar$, which is equivalent to the spin-flip transition between $\pm\frac{1}{2}\hbar$ and $\mp\frac{1}{2}\hbar$. So interchange of massless spin 1 quanta interacting with an orbiting spin $\frac{1}{2}$ particle, with probability reduced by a factor of $1/137$ compared to the Coulomb interaction, is consistent with our picture. We get the same results as QED to order $1/137^2$ without any need for gauge invariance.

The same argument shows that the Coulomb interaction, which only depends on the direction toward the attracting center and the local acceleration its field produces is spin independent and velocity independent, while the spin flip transition depends on either the traveling photon interacting with the moving charge or the magnetic field produced by the center acting on the moving charge depending on which description you wish to use. Thus we can distinguish electric from magnetic forces as static or velocity dependent as we did in Maxwell's Equations or as spin dependent or spin-independent in the quantum theory. The pictures support each other.

When we come to gravity, the positive protons, negative electrons and neutral neutrons all attract each other as well as particles of the same mass with thestandard Newtonian interaction. The velocity dependent forces only show up in the bending of starlight by the sun and the precession of the perihelion of Mercury. As we have argued elsewhere, both effects are explained by spin 2 gravitons.[16] In terms of spin, this is explicable if, as before the Newtonian term is spin independent, while the spin dependence (down by $GMm/\hbar c$) allows only the five distinct triplet-triplet transitions. In terms of velocity dependence this implies the extreme non-locality of coupling the motion of both objects by two velocity dependencies. This is, of course, another way of saying that the interaction is scalar (i.e. Newtonian) -tensor and distinct from the scalar (i.e. Coulombic) -vector electromagnetic interaction. All of this fits neatly into the crossing symmetry argument for anti-gravity and hence reinforces it.

8. PRINCIPLES AND RESULTS OF MY APPROACH

In order to summarize the position I take with respect to the establishment, I quote from a recent letter to a colleague:

Our principles are finiteness, discreteness, finite computability, absolute non-uniqueness* and our procedures must be strictly constructive. For us, the mathematics in which the Book of Nature is written is finite *and* discrete. We model nature by *context sensitive* bits of information. In this sense we are participant observers.

Physics, as a science of measurement, can expect that at least some of the structures uncovered in nature could result from the way we perform experiments. For example, Stillman Drake[17] has discovered that Galileo measured the ratio of the time it takes for a pendulum to swing to the vertical through a small arc to the time it takes a body to fall from rest through an equal distance as $948/850 = 1.108\ 2....$ We now compute this ratio as $\pi/2\sqrt{2} = 1.110\ 7....$ Thus Galileo *measured* this constant to about 0.3 % accuracy (Ref. 13). fall and pendulums oscillate" independent of the units of length and time.

In any theory satisfying our principles which counts events by a single sequence of integers, any metric when extended to large counts can have at most *three* homogeneous and isotropic dimensions in our finite and discrete sense.[18] More complex degrees of freedom, indirectly inferred to be present at "short distance" automatically "compactify". Hence we can expect to observe at most three absolutely conserved quantum numbers at macroscopic distances and times. Guided by current experience, we can take these to be lepton number, charge (or the z-component of weak isospin), and baryon number. These are reflected in the experimentally

⋆ eg. In the absence of further information, all members of a (necessarily finite) collection must be given equal weight.

uncontroverted stability of the proton, electron and electron-type neutrino. This choice is empirical but not arbitrary, since structures with appropriate conservation laws isomorphic with this interpretation arise in our construction.

Take the chiral neutrino as specifying two states with lepton number ± 1 and no charge. They couple to the neutral vector boson Z_0. In the absence of additional information, these states *close.* The 4 electron states couple to two helical gamma's and the coulomb interaction. These seven states can be generated by any 3-vertex which includes two electron states and an appropriate gamma. These $3 + 7 = 10$ states when considered together then generate the $W^{\pm}$. This completes the leptonic sector in the first generation of the standard model of quarks and leptons. Bit-strings of length 6 provide a compact representation of these states which *closes* under *discrimination* (exclusive-or), and conserves both lepton number and the z component of weak isospin at each vertex. No unobserved states are predicted at this level of complexity, and no observed states are missing.

Two flavors of spin $\frac{1}{2}$ quarks and three colored gluons provide the seven elements of the baryonic sector which generate the inferred 127 quark-antiquark, 3 quark, 3 antiquark, 8 gluon ... states (16 fermions times a color octet minus the state with no quantum numbers) needed for the "valence level" description of the quark model. Bit-strings of length 8 provide a compact model using seven *discriminately independent* basis strings and again close producing only the appropriate states at this level of complexity. Combining them with the leptonic states allows the strings representing the vector bosons to be extended to length 14, producing all the vertices and only the vertices which occur in the standard weak-electromagnetic unification of the first generation of the standard model. Extending the whole scheme to strings of length 16 we get the three generations which are observed experimentally (and a slot with the quantum numbers of the top quark). The quarks have baryon number $1/3$ and charges $\pm 1/3, \pm 2/3$ as required. The $0 \leftrightarrow 1$ bit-string symmetry makes CPT invariance automatic. As already noted, if we have only three large distance quantum numbers color (although conserved) is confined, and generation number is not conserved in weak decays.

We are now in a position to talk about the 137. *Empirically* only one of the 137 states required by the standard model of quarks and leptons corresponds to the coulomb interaction. Hence, by our principle of absolute non-uniqueness, the probability of this interaction occurring is 1/137 in the absence of further information.

Our basic quantum mechanical postulates are that (a) the square of the invariant interval between two events connected by a "particle" which carries conserved quantum numbers and conserved 3-momentum between them, is the product of two integers times $(h/mc)^2$ and that (b) space-like correlations for particle states with the same constant velocity can occur only an integer number n_λ of deBroglie wavelengths ($\lambda = h/p$) apart. These give us relativistic kinematics and the usual commutation relations for position, momentum and angular momentum.

If we model the hydrogen atom by events a distance r from a center we must have $n_\lambda \lambda = 2\pi r$. This interpretation is supported by noting that if the radius vector sweeps out equal areas in equal times, $\Delta A/\lambda^2 = (n_\lambda^2 - 1/4)(1/2\pi)^2$ and with $\ell = n_\lambda - 1/2$, the angular momentum is $\ell(\ell+1)\hbar^2$. Since these events occur with probability $1/137n_\lambda$, we get (Ref. 11) the relativistic Bohr formula[19] for the hydrogen spectrum. When we include a second degree of freedom, and take proper account of the ambiguities in counting, we get not only the Sommerfeld formula but the formula for α to which you object. Similarly, the fact that the basic Fermi interaction involves 16 possible states of four fermions gives us $\sqrt{2}G_F = (256m_p)^{-2}$ where the square root comes from the conventional interaction Lagrangian to which experimental numbers are compared, and m_p comes from the stability of the proton.

I am willing to grant that the original Amson, Bastin, Kilmister, Parker-Rhodes sequence 3,10,137,$2^{127}+136$, STOP —discovered in 1961 after a decade of disciplined research — does *sound* like numerology. That was my own first response. I was willing to think there might be something to it *after* I had used the Dyson argument to identify the last two numbers as the maximum number of charged particle pairs or baryons one can *count* within the Compton wavelengths $h/2mc$ or h/m_pc by, respectively, electrostatic or gravitostatic means. In fact one of my research objectives until the mid 1980's was to find a way to kill the theory and get on to something more promising. What convinced me that the evolving construction could be the starting point for a *new* physics and physical cosmology was McGoveran's calculation of the Sommerfeld formula and correction to α plus the fact that the same arguments applied to other coupling constants consistently improved agreement with experiment. I really don't think it fair any longer to call our theory "numerology".

When you assert that the dielectric constant of diamond can be calculated from first principles, you must assume (correct me if I am wrong) that you already *know* a number of physical constants. Of course one can relate the standards of mass, length and time as measured in the laboratory to three dimensional constants (which could be $c, \hbar$ and G) that occur, self-consistently, in several structures derived from "first principles". But to get to diamond you will also need α, m_e, and M_C in well defined relation to those units. Otherwise your calculation has no potential empirical test.

You must admit that, in your framework, these three numbers are too complicated to calculate from first principles. In fact, when Weinberg discusses *how* a finite coupling constant might emerge from currently acceptable theory, his errors are so large that he cannot even contemplate a quantitative prediction that can be confronted by experiment. In contrast my values for α, and m_e are good to six or seven significant figures, and I can argue that my "first principles" allow me to predict that the common isotopes of carbon will have masses of approximately 12 and 13 proton masses. I have systematic ways of improving these estimates, and also— thanks to my physical cosmology — of estimating the relative abundance of these two isotopes on a terrestrial-type planet with an age of 4.5×10^9 years in a solar system of the kind in which we are conducting experiments. Somewhere along this line my calculation from "first principles" would find empirical supplements useful, but I believe no where near as soon as yours.

I would locate the difference in point of view between us as coming from our different views of "space-time". If the "quantum vacuum" (which I would prefer to call a "quantum plenum") of renormalized second quantized relativistic field theory is the underlying concept, its properties certainly change as you "squeeze" it. The received wisdom today is that if the squeezing produces an energy density something like 10^{16} times that of the proton the "strong", "electromagnetic" and "weak" interactions come together (one basic "coupling constant" — grand unification) and that if one can extend the theory another three orders of magnitude, gravitation will find its appropriate place in the scheme. It seems to me that adopting "principles", however beautiful, that force one to go thirteen orders of magnitude beyond currently possible experimental tests to define fundamental parameters is — to say the least — a peculiar methodology for a physicist.

On the other hand, if one starts here and now with separated charges and massive particles and "empty" or "constructed" space as the first approximation, one can *measure* masses and coupling constants in a well defined way. If one can — as we claim — get good approximations for these values from "first principles" and systematically improve the predictions, I fail to see why such values cannot be considered "primordial". After the universe becomes optically thin, we predict about 2×10^{-10} baryons per photon. This both is in agreement with observation and supports our "empty space" philosophy.

I have recently succeeded[20] in deriving the solutions of the free particle Dirac equation by summing the "vacuum fluctuations" in such a way that they cancel out leaving the *physical* mass of the particle as a first approximation. The calculation is simple, and I will be happy to write it out for you if you are interested. The hydrogen atom and fine structure we already have, as noted above. "Running" coupling constants are unitarity corrections to the low energy values from which we start. We should have the Lamb shift, etc. before too long.

Since I know you are concerned about "time", I beg you to consider the proposition that, for finite beings who can count, keep records, and retrieve those records, time is simply a finite counting parameter for these recorded or remembered events which can be put into correspondence with the integers interpreted as irreversible counting numbers. In the absence of further information, events which are assigned to the same integer must be given equal weight. This is one way to see why "in-distinguishables" must enter our theory in an essential way and lead us into new mathematical territory.

9. CONCLUSION

All we need is a major experimental success, such as anti-gravity, to put us on the map.

ON TO THE 21^{ST} CENTURY!

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PREDICTIONS FROM A FUNDAMENTAL THEORY

Table: **Coupling constants, mass ratios and cosmological parameters** predicted by the finite and discrete unification of quantum mechanics and relativity. Empirical Input: $c, \hbar$ and m_p as understood in the "Review of Particle Properties", Particle Data Group, *Physics Letters*, **B 239**, 12 April 1990.

COUPLING CONSTANTS

Coupling Constant	Calculated	Observed
$G^{-1}\frac{\hbar c}{m_p^2}$	$[2^{127}+136]\times[1-\frac{1}{3\cdot 7\cdot 10}] = 1.693\ 37\ldots\times 10^{38}$	$[1.69358(21)\times 10^{38}]$
$G_F m_p^2/\hbar c$	$[256^2\sqrt{2}]^{-1}\times[1-\frac{1}{3\cdot 7}] = 1.02\ 758\ldots\times 10^{-5}$	$[1.02\ 682(2)\times 10^{-5}]$
$sin^2\theta_{Weak}$	$0.25[1-\frac{1}{3\cdot 7}]^2 = 0.2267\ldots$	$[0.2259(46)]$
$\alpha^{-1}(m_e)$	$137\times[1-\frac{1}{30\times 127}]^{-1} = 137.0359\ 674\ldots$	$[137.0359\ 895(61)]$
$G^2_{\pi N\bar{N}}$	$[(\frac{2M_N}{m_\pi})^2-1]^{\frac{1}{2}} = [195]^{\frac{1}{2}} = 13.96..$	$[13, 3(3), > 13.9?]$

MASS RATIOS

Mass ratio	Calculated	Observed
m_p/m_e	$\frac{137\pi}{\frac{3}{14}\left(1+\frac{2}{7}+\frac{4}{49}\right)\frac{4}{5}} = 1836.15\ 1497\ldots$	$[1836.15\ 2701(37)]$
$m_\pi^\pm/m_e$	$275[1-\frac{2}{2\cdot 3\cdot 7\cdot 7}] = 273.12\ 92\ldots$	$[273.12\ 67(4)]$
m_{π^0}/m_e	$274[1-\frac{3}{2\cdot 3\cdot 7\cdot 2}] = 264.2\ 143\ldots$	$[264.1\ 373(6)]$
m_μ/m_e	$3\cdot 7\cdot 10[1-\frac{3}{3\cdot 7\cdot 10}] = 207$	$[206.768\ 26(13)]$

COSMOLOGICAL PARAMETERS

Parameter	Calculated	Observed
$\Omega_{vis}/\Omega_{closure}$	0.01175	$[0.005 \lesssim \Omega \lesssim 0.02]$
Baryons/Photon	$\frac{1}{256^4} = 2.328\ldots\times 10^{-10}$	$\sim 2\times 10^{-10}$
M_{dark}/M_{vis}	12.7	> 10