The Uniqueness of the World

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Abstract

We follow some (wild) speculations on trying to understand the uniqueness of our physical world, from the field concept to F-Theory.

KEY WORDS: Unification of forces, Uniqueness, High-Road approach, M and F Theories.

*Dedicated to Emilio Santos in his 70th birthday. I have enjoyed discussions with Emilio on physics for the last 40 years.
1　Special Relativity

Is the Universe we experience derivable “a priori”? That is, are there enough reasonable assumptions from which one can understand the major features we observe by looking at the world around us? Some physicists (e.g. S. L. Glashow) call this the “top-bottom” approach, or the High Road to do physics. Einstein since around 1920 thought so, but this view has been fairly unpopular. In this essay we are going to explore some old and recent avenues with this idea in mind.

We notice we live in three spatial dimension, with another dimension, time, flowing forward irrespective of us; we change places at will, but, alas, time is not under our command. In a first view we approach space as a continuum, and associate somewhat arbitrarily three real number to specify a position. It is perfectly possible that in the future we dispense with the reals and substitute for some other class of numbers (integers?). In fact, we can argue that the reals can never really be observable, so in a strictly positivistic approach they should not be used. Besides positions, we observe motions; time becomes entangled with space, and the simplest thing is to attribute some real number as time to mark events. (Static) geometry gives way to kinematics.

Experience determines soon a first limitation: velocities are not to be arbitrarily large; special relativity comes in. The lesson is, I believe, nature abhors infinities, so no observable can attain infinite values (the same argument goes also against the real numbers, of course; it also hints towards atomicity, see below). Velocity $c$ plays the role of infinite velocity in the following sense: for an “observer” moving at $c$, it passes no time: it is like going with infinity speed in prerelativistic physics. By continuity, time slows down when we run. Special relativity makes a greater strain in our intuition than the general theory (Dirac is one of few who understood and explicitly said that: the conceptual jump from space to spacetime is bigger than from flat space to curved), because absolute (maximal) velocity, instead of absolute time, is more counterintuitive and paradoxical that, say, the geometry of space being determined by its matter content. Maximal velocity leads to relative time, and one of the big tenets of classical intuition (and classical philosophy), the steady flowing of an universal time, falls into pieces: time goes along characteristically with the moving observer.

So everything physical is propagated at finite speed. Including forces, of course. Which forces? Well, at least macroscopically we observe two forces, due to weight and charges. The main feature of both, we have learned painfully in the last hundred years, is that they are gauge forces. That is, there is a geometric construction, the gauge arbitrariness being close to the patch freedom or coordinate choice in the geometry of manifolds: consistency in overlapping patches leads to the gauge group, and the concordance of the equations with gauge invariance leads to conservation laws, the most conspicuous feature of both gravitation and electricity. In return, this implies the field laws, as it gives freedom to the propagating fields and, in retrospect, favours, if not selects, the macroscopic dimension of
space (-time): it is better to be in a \((1, 3)\) manifold as regards only these two forces.

2 Electromagnetism

Let us be more specific. Force with finite propagation speed singles out a field description, as Faraday and Maxwell claimed already in the XIX century: no newtonian action-at-distance, but fields as propagating agents. The electric field acts in a point of space, and charged matter responds by moving under the influence of the local field; by reaction, the charged matter distribution controls the existence and propagation of the fields. The primitive idea (Newton) that particles act among themselves with no further reality, is superseded in the field approach, which acquires degrees of freedom of its own: Maxwell predicted electromagnetic waves, one of the most sensational discoveries in the history of science.

Let us call \(F\) the (electromagnetic, em) field, and \(j\) the charged matter distribution; we emphasize “charged”, because we learn soon that matter, indeed most of the matter, is neutral (= globally uncharged). The relation between \(F\) and \(j\) must be of contact type (today expressed as local (differential) equations in the numerical continuum; how will it be in the future?). The liberties of the field manifest themselves in the differential character of the equation: so, through the integration constant (or function), the field exhibits its own degrees of freedom. Thus one of the simplest formulation could be, with \(\delta\) some first order differential operator

\[
\delta F = j \quad (1)
\]

There are interesting solutions even when \(j = 0\). This formula is only half of the truth: it must be appended by stating how does charged matter move in given fields (Lorentz force, see below). If \(F\) and \(j\) are vector/tensor magnitudes, the operator \(\delta\) could be nilpotent, \(\delta^2 = 0\): technically, if they are \(p\)-forms, the only natural differential operators are of square zero. Hence

\[
\delta j = 0 \quad (2)
\]

which is an invariance law: only conserved electric matter can be coupled to the em field. As \(j\) is a \(p\)-form, integration gives charge stability: \(Q(t_0) = Q(t_1)\). This is the distinguished feature of gauge theories, an automatic conservation law.

Three important consequences can be drawn from this: first, assuming \(j\) has the relativistic character of a 4-vector, \(\Pi\) should be read as \(3 = 3\) conditions, and not \(4 = 4\), that is, only conserved currents are to be coupled: conservation of electric charge follows. Secondly, gauge invariance: the Lorentz force, i.e. the relation by which \(F\) determines the motion of charges, written in hamiltonian or lagrangian form, as it should in any sensible
formalism, must be in terms of a first integral of $F$, and then the 1-form $A$, such $F = dA$, either postulated, or coming from $dF = 0$, should enjoy some indeterminacy: $A \to A + d\Lambda$, where $\Lambda$ is the gauge function. This is the patch arbitrariness we talked about above; in fact, in some spacetime topologies $F$ is always global, as curvature of the connection, but $A$ is not: $F$ should be closed but not necessarily exact. Properly, this gauge invariance e.g. in the lagrangian formulation (which we omit) is the true reason of charge conservation through the important Noether second theorem: invariance under functional transformations imply relations among the equations of motion, the fact that here we have $3 = 3$, not $4 = 4$ equations. Third consequence, there is conservation of flux: a single point charge $q$ should generate a field decreasing with the $1/r^2$ law, as flux conservation follows from (1): a sphere no matter how large surrounding the charge should encompass the same flux.

Therefore, no wonder about the $1/r^2$ law, the same as Newton discovered in gravitation, and for the same reason. Does this tell us something about the geometry/dimensions of space? Well, it makes the case for a preference for three extended space dimensions: in one space dimension only, the Coulomb law will determine confinement, there are not degrees for the field; also in two dimensions (logarithmic potential), whereas in four space dimensions the $1/r^2$ law for the potential is scale invariant, making the orbits unstable (besides complications at the quantum level, like “falling into the center”, etc.). Worse for spacetime dim $> 4$: we conclude the $d = 3$ character of open space as being the most satisfactory setting for an exact geometric force law.

The influence of the field on the motion of matter hinges on how we describe matter; for a single structureless particle with mass $m$, and charge $q$, the simplest equation would be (with $F$ the force and $u$ the 4-velocity)

$$dp_\mu/ds = F = qF_{\mu\nu}u_\nu$$

which is the Lorentz force.

3 Gravitation

What about the geometry of this 3d space or 4d spacetime? As Minkowski saw already in 1909, finite propagation speed hints strongly to a 4d metric spacetime with signature (1, 3): the light cone constitutes the set of light rays. Now we go back to Riemann (whose physical insights are sometimes obscured by his gigantic mathematical prowess); in his geometric studies he already hinted at a selfconsistent determination of the geometry of space (not of spacetime) on physical grounds, and therefore to connect matter with curvature. It took more than fifty years for this ideas to fructify, the main stumbling block being the necessity, unthinkable in the pre-Maxwell times Riemann was living, of uniting
space and time. There should be another geometric force which will shape the form of the universe for us. Today it is only too clear how Einstein’s General Relativity program accomplishes this. We have the equivalence principle: a test particle moves upon gravitation universally, depending not on itself but on the surrounding matter: geodesic motion. This is even simpler that the Lorentz force motion, because there is more universality.

The next question is, how much deformation of space (curvature) is produced by (a kilogram of) matter? It is hard to beat Wheeler’s *dictum: space tells matter how to move, matter tells space how to curve* (bend). There is a 4d manifold $\mathcal{V}$ with a metric $g$, and then with a geometric object, $G$, coming from the spacetime structure, necessarily some derivative(s) of the metric $g$, which should be determined by the matter distribution, $T$. So Einstein wrote

$$G = \kappa T$$

(to be compared with eq.(1)) where the constant $\kappa$ converts matter to geometry. But this equation refers to all matter, because there are no “unponderable” matter. The first sensible choice for $T$ is to be a symmetric 2-tensor with positivity requirements and conserved, $\delta T = 0$ (as opposed to the 1-tensor $j$, as there is electrically neutral matter, but not weightless matter). Question arises, exactly as Einstein thought: how to extract, from an arbitrary continuum 4-manifold $\mathcal{V}$, a 2-tensor with gauge invariance (that is, with an automatic conservation law). The struggle of Einstein along November 1915 to fix the right thing is hectic; at the lagrangian level, Hilbert beat him for a week. But there is nearly only a solution (good mathematics comes in help of good physicists): if $(\mathcal{V}, g)$ is the 4d manifold, and $\text{Riem}$ the $(1, 3)$ Riemann curvature tensor, the only conserved tensor is $G$, ($\delta G = 0$), where

$$G := \text{Ric} - (1/2)g \quad \text{where} \quad \text{Ric} = \text{Tr}_1(\text{Riem})$$

(We write the trace $\text{Tr}_1$ because by $\text{Tr}_2$ we mean $\text{Tr} \text{Ric} = \text{scalar curvature} \ R_{sc}$: the object Hilbert wrote inside a lagrangian). And we repeat the scheme of above: first, there is conservation law, $\delta T = 0$: only conserved matter can be coupled to spacetime curvature (this point, automatic conservation laws has been forcefully argued often by Wheeler). Second, equation (4) should read as $6 = 6$ numbers, not $10 = 10$ (the tensors are symmetric); the rest is the gauge invariance (choice of patches to describe the 4d world). Indeed, the lagrangian, as Emmy Noether taught both Hilbert and Weyl, has a four-function invariance (under change of coordinates), hence there are four constraints among the equations of motion.

Third, the same $1/r^2$ law arises as before, at the level of the geodesic motion $\gamma$, where $\delta \int_{\gamma} ds = 0$, closing into a beautiful circle, because the $1/r^2$ law was the primordial discovered feature, already hidden in Kepler’s first law. Notice the paradox, seldom stated: for a single big mass $M$, the metric far enough away falls as $r^{-1}$, so a closed orbit is elliptical as
in the $r^{-2}$ force law, but the curvature, which plays the role of field intensity, should (and does!) fall off faster, with $r^{-3}$; whereas the electric field of a point charge falls off itself like $r^{-2}$: This is because geodesic motion is inertial (no force); geodesics are fixed by the connection (Christoffel symbols), falling like $r^{-2}$, not by the curvature: electric forces are forces, but inertial “forces” are not. Is there then any role for the curvature? Of course: this is the reason why the moon is more effective than the sun in tidal motion on earth.

It is irresistible to add some comments to the magnitude of Einstein creation (although, I repeat, less innovative that special relativity). Definitive blow to the philosophical standpoint that there is a empty space in which we add things to fill it up: space (and time) is not an “a priori” category: it is created along with the matter in it. Rather, operatively speaking, there is no space if there is no matter, and the latter fixes the former; another blow to a naive realism. In the search for an “a priori” understanding of the world, many prejudices of naive realism fall in the path of the scientific discoveries.

4 Unification

Are they really so different, electricity and gravitation? Both are gauge theories, both universal or nearly so, both ruled by the inverse square law but in the face of it, very different also: two signs for the charge, irrelevance of gravitation at the microscopic realm. It had to be an outsider, an unknown young physicist in the german city of Königsberg (at the moment occupied by the russians) who dared to unite them. The most spectacular feature of Kaluza’s construction (1919) is to account for the essential difference: negative/positive (and hence neutral) electric matter versus just masses, and this by means of a geometric device: let us add a circle at each 4d spacetime point, and describe electric force as prompting motion along the circle (two senses = two signs of the charge), whereas neutral matter moves only in the other 3 large space directions. Even today the boldness of Kaluza idea ranks, to us, close to Riemann’s first inception of geometry as determined by physical effects.

To make a long story short, one would set the ”gravitation” equations in a circle times curved 4d space; the electric force comes automatically, conserved, and with the two signs for the charge. Besides, the disproportionate ratio of electric to gravitiant forces at the atomic scale sets the circle radius very very small (O. Klein, 1926); compared even with the dimensions of atomic nuclei, smaller for a factor of $10^{20}$. But there is a price: a metric $g$ in $(D + 1)$ dimension gives rise, viewed from $D$-dim space, to

$$g_{D+1} \rightarrow g_D + A_D + \phi_D$$

that is, a 1-tensor (em field potential) and an enigmatic 0-tensor (dilaton $\phi$), besides the metric $g$. 
Both Einstein and Kaluza-Klein were far ahead of their times. General relativity layed dormant for physicists until the astrophysical discoveries in the mid-sixties, whereas the idea of extra dimensions did not enter the mainstream of physics until the ’80s, with many unbelievers still today.

Already in 1919 H.Weyl, thus before Kaluza, sought another electrogravitation unification by allowing the scale of the metric $g$ to vary pointwise, but this “gauge” invariance became much more useful as a point-dependent phase in the charged fields.

5 Other Forces

Let us not stop at this. Nature is more versatile. Masses, charges and light do not exhaust the physical world (inspite that Einstein never cared about the rest, un *pecado de orgullo* we should try to avoid). Could there be other forces, not ostensibly expressible with the $1/r^2$ law, and still of geometric (gauge) origin? I confess I have no hint here but to retort to experiments; it is only very difficult to understand atomicity, a conspicuous feature of the natural world, unless there is some quantum description (how, otherwise, does atomicity and discreteness come from?), and some other forces. Or, more forcefully, arbitrarily large division of matter chunks is unoperational: another *Irrelehre* to skip; from Democritus we have learned this option. Indeed, granted the feebleness of gravity forces at the atomic scale, evidence for nonelectric forces in the microworld became incontrovertible in the late 20’s and 30’s: beta radioactivity and particles other than electrons and protons in the nuclei, hence nuclear forces of nonelectromagnetic origin.

The program then was clear: first, one should empirically state the laws of these new forces, try to discover the intimate nature (type of gauge, for example). There is a heroic struggle to uncover the laws of both the strong and weak interactions, which we forcefully omit, which lasted for about forty years, only to state, at the end, the result: both are gauge forces, of course, but both hide this character (none obeys effectively the $1/r^2$ law) with mechanisms we do not fully understand even now: confinement in one case (the strong force), symmetry breaking in the other (weak force). I cite here only two giants: Murray Gell-Mann (working mainly in the weak forces found the gauge group for the strong) and Steven Weinberg (working in the strong forces discovered the broken gauge theory of the weak). Are then four forces too many? On the contrary: to reduce all the observable phenomena to only four types of interactions is a fantastic achievement. Yet not full unification, as even the “electroweak” theory just juxtaposes two gauge theories with an arbitrary mixing angle. The dynamics of the microworld seems to be well described by the gauge forces associated to the group $SU(3)_{QCD} \times (SU(2) \times U(1))_{electroweak}$.

But by now Pandora’s box is open, and we would like to apply Kaluza’s program to these new forces. We learned the lesson of the fifth dimension in the same sense as
Riemann conception: the space (−time) is physically determined, not only with respect to shape, but we should stretch the program towards understanding also the dimension and the signature! Geometry should be as a whole self-consistently determined by matter. I do not see how people totally happy with general relativity are so reluctant to accept dynamically generated extra dimensions for our world; we feel only four, yes, but we also feel matter as continuous and packed, whereas it is discrete and space is practically empty (indeed, nuclear to atomic volume ratio close to $10^{-15}$). And following this line, one should learn the lesson and go beyond: geometry is primary to phenomena, so one must try to understand the extra forces through geometry. In other words, there should be constraints in the extra dimensions, and fixed these, the extant forces will follow. This should be the Top of the top-bottom approach!

This program has not been fulfilled as yet; (it will be el fin de la aventura, the end of science. Inspite J. Horgan, we are still light years away). So we pause for a moment and ask, instead, what consequence will have to allow the dimensions to vary in order to understand the forces, new and old, more geometro.

6 Extended Objects

This is our understanding why extended objects are needed, or at least very welcome, in a theory with more than five dimensions; it is somehow anti-intuitive, so we elaborate a bit. Since the times of Democritus, a constant feature in physics has been to attribute atomicity to matter; atoms should be the building blocks of the Universe. But now, a more versatile point of view emerges: there might be elementary extended objects which should not be operatively understood as made of little point particles. Now, why the extended objects in the first place? I see a very neat geometric/dynamical reason: in a universe with more than five dimensions, and you need them if forces other than electrogravitatory enter, the natural objects are strings or membranes, or higher $p$-branes. Why? The key concept is duality with gauge forces. Namely, electric forces, which we use for abbreviation, come together with magnetic forces, as we know since Ampère and Oersted. Duality for particles (i.e. point particles) occurs in 4 dimension, but duality for strings occur in six, for membranes in 8, and for $p$-Branes in $2(p + 2)$. The dual of a string is a (magnetic) string only in six dimensions: a charged particle in $4d$ describes a worldline, hence couples by the Lorentz force to a 1-form $A$ with a 2-form $F$ as field strength; $F$ dualizes to $\ast F$, another two-form. A string spans a worldsheet, couples to a potential two-form $B$, with a 3-form field strength $G = dB$, dualizing to a Hodge partner only in six dimensions. Similarly for higher $p$-Branes.

Turning the argument around: if there are extra dimensions, to find and deal with extended objects is just too natural. And, passim, we overtake Democritus and Leucipus after 24 centuries: elementary objects are not necessarily pointlike.
Here we hit a technical barrier, which makes one suspect a theoretical scheme going beyond lagrangian quantum field theory is called for: we do not know how to extract full exact consequences of a string theory, not to speak of membranes or higher $p$-branes. For 0- and 1-Branes the Nambu (=extremal volume) and Polyakov (= general-relativistic) formulations are equivalent (although even the nonperturbative regime in string theory escapes us). But for $p > 1$ the minimal and relativity forms are inequivalent... This is why, in our view, $M$-theory (see later) is stagnant. And we did not adress yet another problem: granted there are extra dimensions, and that we do not see them, why and how do they bend (compactify)? Or rather, if all dimensions are finite (compact), why ones are more compact than others?

7 SuperSymmetry

But we still face other bigger problem, in the search for a unique world. Already risen by Einstein, it is the “marble versus wood” problem.

The universe is structured like a building, with bricks held together by a glue. The force fields are the glue, the fermions are the bricks. Is this dichotomy fundamental? Quantum Mechanics comes to stress the difference, making it more poignant: the exclusion principle, which determines the existence of structures in the Universe, does not apply to the coherent states of the particles carrying the gauge forces, namely the classical fields. Is there a description in which glue and bricks come together, united but different? We tried unification, since Kaluza, for interactions (glue). Now we ask for forces and matter itself. I do not dare to say that supersymmetry ($\text{Susy}$) is compelling, but certainly looks as a provisional phenomenological step forward: if there is a symmetry between bricks and glue, we “understand” why the two are necessary. So Susy comes to the fore, but from a lateral entrance, however: the Susy partners of the extant particles are new particles: in general, quarks and leptons go with the fundamental representations of the gauge groups, whereas the glues (gluons, photons) go with the adjoint. This were only natural, for example, if the “bricks” have some solitonic character.

Supersymmetry extends to everything; simple quantum mechanics, quantum field theory, electromagnetism (qed), gravitation, etc., have more or less natural enlargements, becoming supersymmetric. There is the so-called minimal extension of the standard model (MSSM), with some phenomenological support (coincidence of the running coupling constants at a very high scale, aprox $10^{16}$ GeV). The most natural supersymmetry occurs because of the octonions: it is the triality isomorphism between the three 8-dim irreps of the Spin(8) group; in fact, this supersymmetry lies at the base of both superstring theory, 11-dim supergravity, and $M$-Theory. The three irreps $8_v, 8_L$ and $8_R$ realize $\text{Spin}(8)/\mathbb{Z}_2$.

With troubles: we have not seen, so far, a single Susy partner of extant particles/
force carriers. With advantages, in the sense of that supersymmetry limits the dimensions and even the nature of the extended objects. For example, superstrings live happy in ten dimensions, but gravitons are even happier in eleven, with a membrane floating around. So Susy seems a step forward in the uniqueness program we address here.

It is worth recalling how, since 1974, the candidate for big unification has changed. Once the electroweak theory passed the first tests (neutral currents do exist; $W^\pm$ and $Z$ found later), Georgi and Glashow proposed the first Grand Unification model, based in the group SU(5). Insufficient, with neutrinos massive. Then superstrings came along, with the veiled promise to unify even gravitation in a convergent (renormalizable) scheme (1976). Too early. In 1980 gravitation reached the climax together with Susy, producing a momentaneous distraction (M. Duff) from superstrings: eleven dimension supergravity is seen at our mundane 4$d$ world as a rich theory with 8 gravitinos (for example). *Embarras de richesse*? On the contrary, the gauge group is not big enough to encompass the group of the standard model, which is a geometric group: $O(1) \times U(1) \times Sp(1) \times Aut_0(Oct)$, or $Z_2 \times SO(2) \times SU(2) \times SU(3)$. Here $O(1)$ is PCT and the last group is $SU(3) \subset G_2$, the little group of octonion automorphisms.

Then in 1984/5 the superstring revolution came, with the promise of another T.O.E. The main new ingredient was uniqueness: there are only five consistent superstring theories, all living in $10 = (1,9)$ dimensions, all incorporating gravity, all supersymmetric, some including two unique gauge groups...

### 8 M-Theory

By now we have uncovered the three ingredients I want to stress in the program for a better understanding of the world around us: extra dimensions, extended object and supersymmetry. Supergravity and the different string theories fuse in the new, beautiful $M$-theory (Townsend, Witten and Polchinski) who arose in 1995. Beautiful but distant: after ten years, we are sill in the beginning of understanding it, no knowing its inner fabric. It is fairly unique and rigid (no coupling constants to adjust), but on the face of it, not yet thoroughly satisfactory.

Ten years have barely passed, yes, and where do we stand? The initial hopes of this $M$-theory did not materialize, and even the most optimistic persons (Ed Witten) seem to have lost steam. At this point we want to pinpoint some shortcomings of the present $M$-theory and signal one potentially interesting new avenue.

First of all the gauge group of the standard model is not reproduced; in fact the natural gauge group is too narrow, and some string groups like $E_8 \times E_8$ come “out of the blue”. Secondly, gravitation appears inextricably mixed with the other forces, and one
would like to separate it from gauge forces, granted the insignificance of gravitation at the atomic scale. In the third place, although $M$-theory is set with a maximum $11 = (1, 10)$ dimensions, strings live in ten and ourselves in four uncompactified. We shall finish by enunciating $F$-theory, an invention of C. Vafa (1996) which deserves serious considerations.

9 F-Theory

According P. Ramond and B. Kostant (1999), the 11-dim Supergravity multiplet is related to the octonionic projective (Moufang) plane $OP^2$, which is the exceptional symmetric space $OP^2 = F_4/\text{Spin}(9)$; for example, the triplet: graviton (+44) - gravitino (−128) + 3-form (+84) comes from the Euler number (3) of $OP^2$, generated, as irreps of $\text{Spin}(9)$, by the identity representation of the group $F_4$. As remarked above, the particle pattern does not naturally correspond to what we see (or expect to see). Is there a natural extension, conserving the aesthetic appeal, and enlarging the situation?

C. Vafa advanced already in 1996 a possible extension (called $F$-theory) in order to incorporate the $IIB$ string theory in the same footing as the other string theories. But with the projective insight of Ramond, there is a better formulation of this $F$-theory: it is a theory living in $12 = (2, 10)$ dimensions, allowing for a queer extended object (a $(2, 2)$ supermembrane) and with a temptative particle content expressable in the complex extension (Atiyah) of the Moufang plane. Namely

$$Y = OP^2_C = E_6/O(10) \times O(2)$$

(7)

(More precisely $Y := (E_6/Z_3)/[(\text{Spin}(10) \times U(1))/Z_2]$). The particle supermultiplet has now 27 members (Euler number of $OP^2_C$), it is still supersymmetric, and offering more than enough room (in fact, too much!) to encompass the experimental (and some future!) multiplets. The two big groups above are distinguished: $E_6$ is the best candidate for Grand Unification (all nongravitatory forces) and $\text{Spin}^c(10)$ is the compact part of $SO(10, 2) = Sp(2, Oct)$, the maximal extension of the Cartan identity $B_2 = C_2$. The associated Ramond-Kostant multiplet has now $2 \times 32768$ states (!), and neither graviton nor gravitino(s) appear. It is too early to see how this gigantic supermultiplet shrinks to the 128 − 128 states of the $m = 0$ multiplet of the Minimal Supersymmetric Standard Model. The new scheme keeps most of the nice features as before, but mathematically is simpler; for example, the supersymmetric algebra in twelve dimensions contains just the “de Sitter” group generators, presumably signaling the kinematic part, and then just a selfdual sixform, which points to a special matter content. Finally, the $27 = 3^3$ number for the multiplets makes one to think both in the number of generations as well as the number of colors. Only the future will tell us if Nature has chosen this wonderful and highly unique structure to describe our world.