

ESSAY

What Can Elementary Particles Tell Us About the World in Which We Live?¹

RONALD A. BRYAN

*Department of Physics
Texas A & M University, College Station, TX 77843-4242
e-mail: bryan@physics.tamu.edu*

Abstract—What kind of space-time do we live in? Does it extend beyond the four dimensions of ordinary space and time? In physicists' efforts to explain the origin of elementary Dirac particles, namely the 12 kinds of quarks and leptons, they find that they are driven to as many as 7 or 8 additional space-like dimensions. They generally assume that the extra dimensions are curled up into tiny circles or generalizations thereof, with diameters of the order of 10^{-34} meter. These models tend to be quite complex. However, I will argue that it may be much easier to model these quarks and leptons if we assume that the extra dimensions are flat, that is, stretch out to infinity. What keeps quarks and leptons (and us) from drifting off into the higher dimensions may be a local "well" in space (a soliton) generated by the particles' field equations. Furthermore, only four extra dimensions may be needed.

If there really are four extra dimensions besides the ordinary four, then why don't we see them? It may be that many people who have had an out-of-body or near-death experience (NDE) *have* seen the extra dimensions. For example, the "tunnel" in the NDE may lead to another local universe like our own, only situated in another "well" in the extra dimensions. In the model that I will describe, quarks and leptons, which are accelerated to sufficiently high energies, can escape our local space-time "well" and travel freely in eight dimensions, as our consciousnesses seem to be able to do. Could it be that large configurations of these particles might even constitute spaceships, the UFOs that seem to come out of nowhere? Higher dimensions may also provide avenues for information transfer ascribed to ESP.

Keywords: elementary particle physics—extra dimensions—psychic phenomena

1. Introduction: Elementary Dirac Particles and Extra Dimensions

Consider the ordinary hydrogen atom, pictured in Figure 1 as Niels Bohr saw it, with the electron orbiting the proton. If you blew up the atom to be as large as the tip of your little finger, then the tip of your little finger, scaled up like-

¹This paper is an extension of a talk given at the annual meeting of the Society of Scientific Exploration, held at the University of Virginia, Charlottesville, VA, May 27–30, 1998.

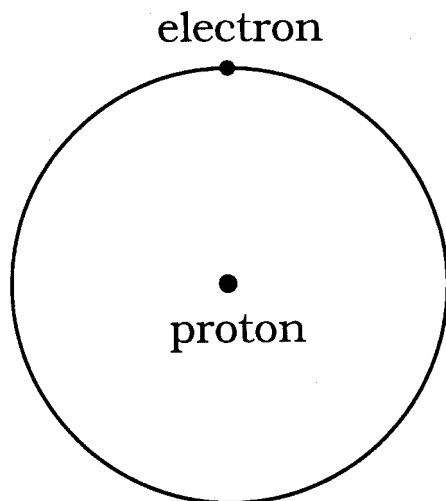


Fig. 1. Electron orbiting proton in the Bohr Model of the hydrogen atom.

wise, would be as large as Saturn. The electron was the first elementary particle to be discovered (by J. J. Thomson in 1897, in a gas discharge tube, similar in principle to a neon sign).

Today we know that there are (at least) six kinds of electrons: the e , ν_e , μ , ν_μ , τ , and ν_τ ; namely, the electron, the electron neutrino, the muon, the mu neutrino, the tau, and the tau neutrino. These particles are like brothers and sisters, in that they all obey the Dirac equation of quantum mechanics. (The Dirac equation is a kind of theoretical quantum device that generates particle waves from space-time.) This means that these particles can also appear as antiparticles (*e.g.*, the anti-electron is the positron) and all have an intrinsic spinning motion with angular momentum $\hbar/2$ (where \hbar is Planck's constant divided by 2π), which can point either up or down. The e , μ , and τ are identical (with the same negative electric charge) except that they have different masses. The neutrinos are identical, too, except for their masses, which might be extremely small (we aren't sure) (Particle Data Group, 1998). (Neutrinos have no charge and at typical reactor energies can travel 25 light-years in lead before deflecting.)

These six kinds of electrons are called leptons. Leptons are incredibly small. If you blew up any one of them to be as big as the tip of your finger, then the tip of your finger, increased proportionally, would be much bigger than our solar system and stretch out toward the nearest star, or perhaps even beyond (we don't know) (Particle Data Group, 1998).

The other constituent of the hydrogen atom, the proton, is far smaller than it appears in Figure 1. Nevertheless, it contains three quarks, as shown in Figure 2.

the proton

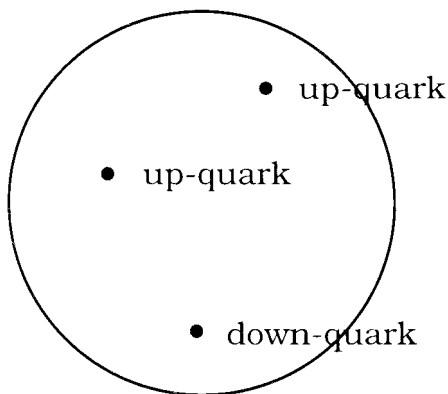


Fig. 2. The quarks in the proton.

These quarks occupy as little volume as the electron does, although they are much heavier. They were discovered at the Stanford Linear Accelerator Center around 1968 in electron–proton scattering experiments. Other kinds of quarks have been discovered since then, and now we know of six types. They have the following amusing names: up, down, charm, strange, top, and bottom. They too are like brothers and sisters in that they all obey the Dirac equation of quantum mechanics, exist in particle or antiparticle mode, and have two possible spin directions. They are like cousins to the six kinds of electrons. They differ from these leptons in that they have never been seen alone; they only occur in triplets, like the proton, or in quark–antiquark pairs, like the pi meson. They are well described by a theory known as Quantum Chromodynamics.

I have plotted the leptons and quarks versus their rest-mass energies in Figure 3. (For example, the electron’s rest-mass energy, as indicated on the vertical axis, is $Mc^2 = 0.5 \text{ MeV} = 0.5 \text{ Million electron Volts}$, corresponding to a particle-mass $M = 9 \times 10^{-31} \text{ kg}$; $c = \text{speed of light}$.) A pair of quarks and a pair of leptons comprise each generation, and there are three generations (Particle Data Group, 1998) (see Figure 3).

Because there are so many kinds of leptons and quarks, many physicists tried to model them as bound states of smaller, more elementary particles, variously called rishons, preons, subquarks, *etc.* The idea was that just as the hydrogen atom has (infinitely) many excited states, perhaps the quarks and leptons are just different configurations of two or three smaller particles. However, these subparticle models turned out to be about as complicated as the quarks and leptons that they were supposed to predict, and in fact, predicted far too many other kinds of particles that have never been seen.

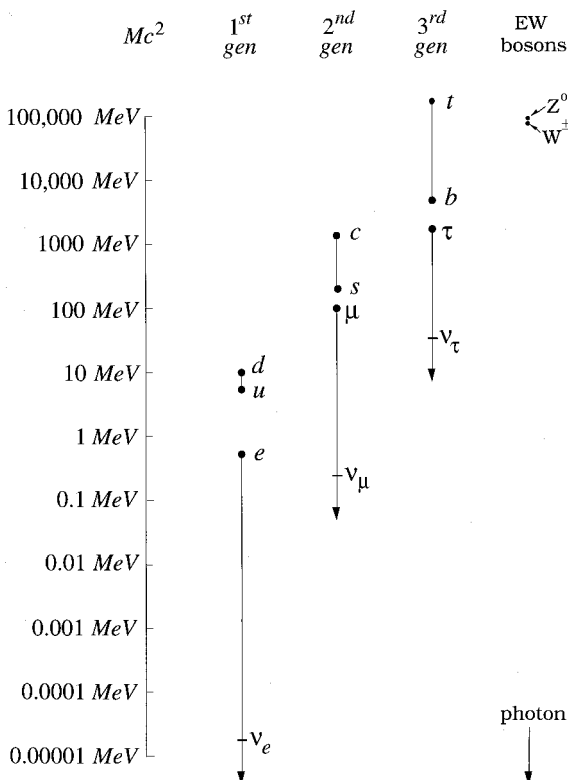


Fig. 3. The three generations of quarks and leptons plotted versus rest-mass energy; weak-isospin pairs are joined. Quarks come in three “colors” (not shown), and leptons in one. The electroweak bosons, Z^0 , W^+ , and W^- , and (massless) photon are also plotted. The masses of the neutrinos are not known, but their experimental upper limits are indicated as horizontal bars. For comparison, the rest-mass energy of the proton is 938 MeV.

These days, most physicists trying to model quarks and leptons turn to higher dimensions. They basically generalize a gravitational theory proposed by Kaluza and Klein in the 1920s, where these authors added another spacelike dimension to the three of space and one of time in an attempt to unify electromagnetism with gravity (see, *e.g.*, Lee, 1984). This fifth dimension did not stretch out to infinity like ordinary dimensions but was taken to be a circle. In fact, an incredibly small circle. The radius had to be the order of 10^{-34} cm for the theory to predict the correct charge for the electron (Miller, 1980).

To help visualize these higher dimensions, let’s consider some projections. For definiteness, first consider ordinary three-dimensional space. I’ll portray it in Figure 4 as a large block, but I will think of space as stretching out to infinity in each direction. (Actually, this is a *model* of space, *i.e.*, Cartesian space; one assumes that space can be divided into little cubes, each identified by three coordinates.)

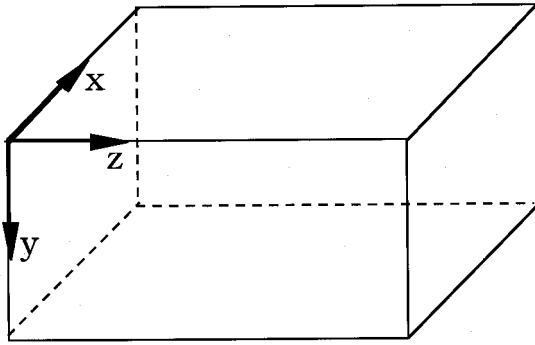


Fig. 4. Three-dimensional Cartesian space.

Now let's eliminate one spacelike dimension, say the (vertical) y -dimension, leaving just the horizontal x - z plane, as in Figure 5.

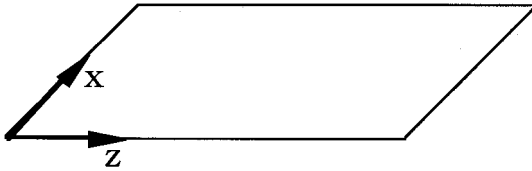


Fig. 5. Two-dimensional Cartesian space.

Let's eliminate the x dimension too. This leaves just one dimension, z , still understood to stretch out to infinity in both directions (Figure 6).

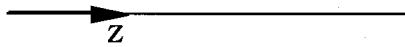


Fig. 6. One-dimensional Cartesian space.

Now let's add an extra dimension, a synthetic dimension not present in ordinary space-time, call it \tilde{x} (see Figure 7). (I will embellish all extra dimensions,

Fig. 7. Two-dimensional Cartesian space consisting of one ordinary dimension (z) and one extra dimension (\tilde{x}).

such as \tilde{x} , with a tilde.) Here, we have recovered a plane, but it is not the usual kind of plane because leptons and quarks, and we ourselves, cannot ordinarily make excursions in the \tilde{x} direction.

In Kaluza–Klein theory (Lee, 1984), the extra dimension is mapped onto a tiny circle, as I mentioned above. This is illustrated in Figure 8 for the case of the extra dimension and one ordinary dimension, say z . It is like rolling the \tilde{x} - z plane up like a sheet of paper to form a tube. The extra dimension is shown in Figure 8 projected on a circle on the left and is denoted \tilde{x} . This theory was only meant to reproduce gravity and electromagnetism. However, since the 1920s, 11 quarks and leptons have been discovered in addition to the electron.

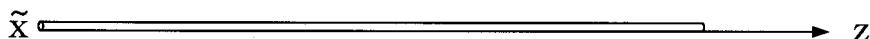


Fig. 8. One ordinary dimension and the extra Kaluza–Klein dimension \tilde{x} , which appears as a minuscule circle of radius of the order of 10^{-34} m.

Now, it may be that gravity has no more to do with the mass spectrum of quarks and leptons than it has to do with the energy-level spectrum of the hydrogen atom (in contrast to a basic assumption of Kaluza–Klein and string theory). Nevertheless, the extra dimension can still be useful, as it provides natural space for additional elementary particles. Indeed, physicists have routinely employed *two* extra dimensions for decades to describe a feature of elementary particles called weak isospin.

To understand this feature, picture an electron spinning about an axis in *ordinary* space. This spinning motion is a quantum-mechanical version of the spinning motion of, say, a ball, or the earth about an axis joining the north and south poles, as pictured in Figure 9. The electron is very small, of course, if it has any size at all. We confirm that it has this spinning motion (predicted by the Dirac equation) from the way that it interacts with other particles. The direction of the axis about which the electron is spinning can be recorded by two angles, say θ and ϕ , or equivalently, by the two coordinates of a small area on the surface of a large sphere (say, of unit radius) where the electron's extended spin axis touches the sphere. The latter is pictured in Figure 10.

Now just as the electron has a spinning motion in ordinary space, it also behaves in reactions with other particles as if it had an additional spinning motion in a *synthetic* space (*i.e.*, in extra dimensions). Physicists call this additional spin *weak isospin*. In Figure 11, I have sketched the electron's weak isospin, \tilde{s} , directed to a small area on the synthetic sphere (called the weak isospin sphere or the isospin sphere).

The surface of the isospin sphere can be considered to be two extra dimensions. In a classical (*i.e.*, non-quantum-mechanical) theory, each electron pointing to a different point on the isospin sphere would correspond to a different particle in ordinary space because it would behave differently in its inter-

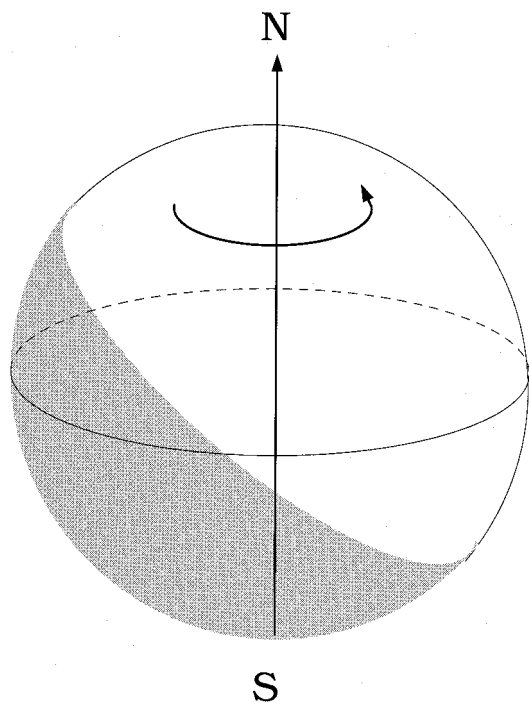


Fig. 9. Earth spinning about its north-south axis.

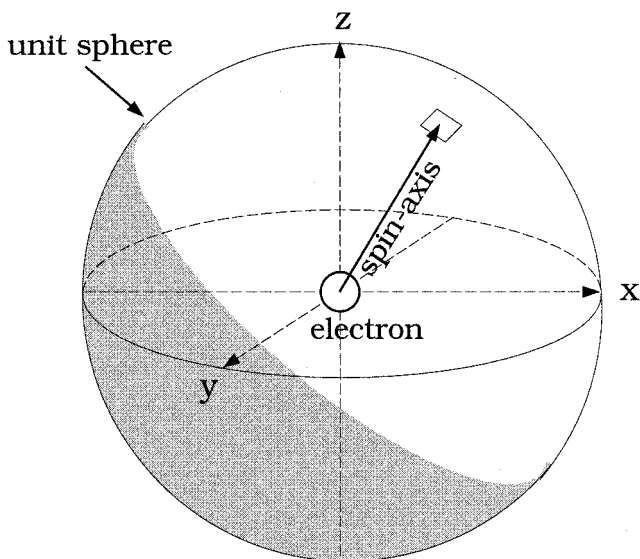


Fig. 10. Unit sphere concentric with electron, and small area on unit sphere where the electron's spin axis touches.

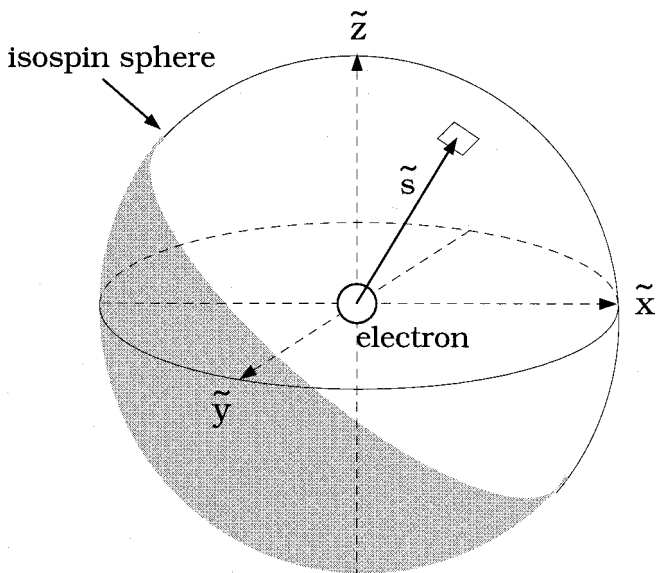


Fig. 11. Electron at center of (unit-radius) weak-isospin sphere; electron's weak-isospin axis, \tilde{s} , directed at small area on two-dimensional surface of sphere.

actions with other particles. Thus, the surface's two extra dimensions would apparently turn one particle into an infinite number of different kinds of particles as seen in ordinary space. However, according to the rules of quantum mechanics, the electron may point only in two directions in ordinary space (up and down), and similarly it may point only in two directions in isospin space. Thus, isospin only doubles the number of electron types. The other member of the electron's doublet is the electron neutrino, ν_e , and its spin is usually taken to point "up." The electron's weak isospin is then taken to point "down." The $e - \nu_e$ doublet is plotted with all of the other doublets in Figure 3, and plotted alone in Figure 12.

Let us suppose that we are constructing a theory of elementary particles, and we incorporate weak isospin to double the number of electrons. Fine, but there are *six* Dirac-particle doublets in Figure 3. How can we account for all six doublets? Well, if we are going to take the two-dimensional surface seriously and say that the electron doublet "lives" on that surface, then I think that it is only reasonable to take the volume within the spherical surface seriously too and say that the electron lives in the entire volume. In this way, I introduce another artificial dimension, the radial dimension, which brings the number of extra dimensions to three. This, as it turns out, gives enough space for an extended Dirac equation (a Dirac equation in $4 + 3 = 7$ dimensions) to generate the up and down quarks as well as the electron and its neutrino, that is, enough space to generate the whole first generation. The $e - \nu_e$ and up-down doublets are plotted in Figure 3 and repeated below in Figure 13.

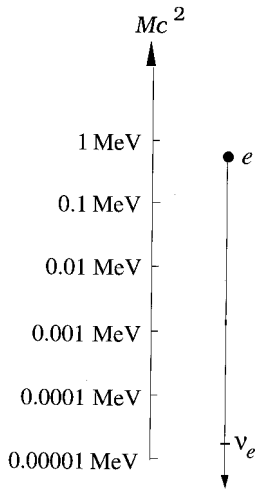


Fig. 12. Plot of $e - \nu_e$ weak-isospin doublet versus rest-mass energy. Upper experimental limit of electron neutrino's mass indicated by horizontal bar.

Although I have suggested that the Dirac particle is trapped within the spherical shell as a marble might rattle around inside a tin can, in fact a softer repelling surface is required to enable the Dirac equation to produce the kind of multiplets that experimentalists actually see. This surface allows the particle to penetrate somewhat and turns out to be what is called a harmonic-

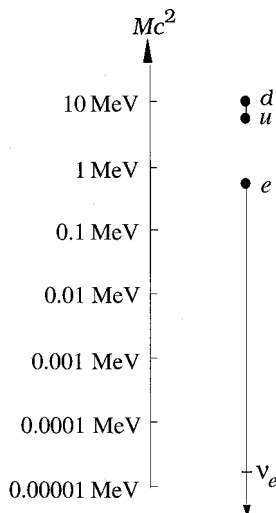


Fig. 13. Up and down quarks, and electron-neutrino and electron, grouped as weak-isospin doublets versus rest-mass energy, Mc^2 . These particles constitute the first generation.

oscillator “well.” Mathematically, it is as if the Dirac particle were connected to the center of the isospin sphere with a rubber band.

As I will explain in the next section, we can generate *all three* generations of quarks and leptons with a Dirac equation if we increase the number of extra dimensions from three to four and again restrain the Dirac particle with a harmonic-oscillator force. This is what I consider the particle-physics evidence that we live not in four, but rather in $4 + 4 = 8$ dimensions (Bryan, 1998, 1999).

It is reasonable to suppose that if four extra dimensions exist within a spherical shell, then these dimensions should exist outside the shell as well, perhaps stretching out to infinity in all extra directions. As far as I know, there is no elementary-particle-physics evidence (yet) for extra dimensions stretching out beyond the shell. However, there may be anecdotal evidence: the widely reported out-of-body experiences (Monroe, 1971), near-death experiences (NDEs) (Moody, 1975), existence of discarnate entities (Roberts, 1972), encounters with UFOs (Mack, 1994), and cases of extrasensory perception (Targ and Puthoff, 1977) suggest long-ranging extra dimensions. I will elaborate on this in the last section of this paper.

In the next section, I give in more technical language the evidence that I have found for four extra dimensions. I will also discuss some limitations of the model. Readers not interested in the details can skip to the last section with little loss in continuity.

2. Some Technical Details

To reproduce the quarks and leptons, it is not at all necessary to take the radius of the extradimensional sphere to be as small as the Kaluza–Klein radius. A radius of the order of 10^{-19} m will suffice. If the surface of the sphere were impenetrable, then quantum mechanics (in this case, a Schrödinger equation acting in the three extra dimensions) would permit a particle to be trapped provided that its mass were m_1 or m_2 or $m_3\dots$ This spectrum of possible mass-states is sketched in Figure 14 as horizontal lines, drawn inside the walls of the “square well.” (The masses’ subscripts merely signify that they are distinct.)

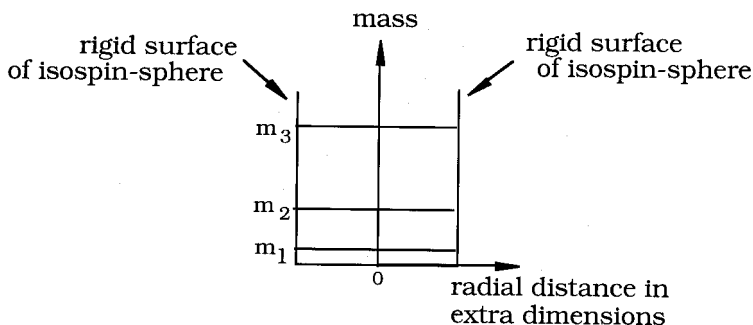


Fig. 14. Quantum-mechanical mass-levels of a particle trapped within a hard spherical shell (a “square well”) in three extra dimensions.

If the hard-shell square well is replaced by a harmonic-oscillator well (which means that the Dirac particle can “push” the wall out somewhat), then the trapped particles appear as **1**, **3**, **6**, **10**, . . . multiplets with allowed masses m_1 , m_2 , m_3 , . . ., as plotted in Figure 15. (Again, the subscripts merely denote distinct masses.) The **1** comprises one particle, the **3** comprises three different kinds of particles, *etc.* These multiplets exhibit what is known as $SU(3)$ symmetry. The triplet **3** has the symmetry of quarks (quarks come in three “colors”) and the singlet **1** has the symmetry of leptons (leptons are “colorless”). The Schrödinger equation can also factor in the two isospin states that come with each multiplet to create a quark doublet and a lepton doublet. The **3** doublet and the **1** doublet then have the same quantum numbers as the physical $u - d$ and the $e - \nu_e$ doublets, respectively, as in Figure 3 or 13. These two doublets, then, constitute the first generation, or family.

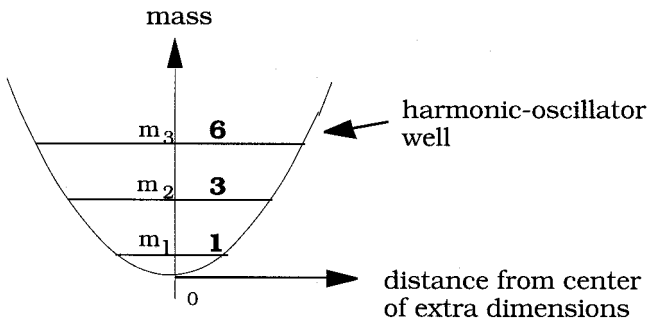


Fig. 15. Particle mass levels predicted by symmetric harmonic-oscillator well in three extra dimensions; $SU(3)$ multiplicities **1**, **3**, **6** indicated.

Note, however, that the harmonic-oscillator well also generates **6s**, as well as **10s**, *etc.* (not shown). These sextuplets and decuplets would be new kinds of Dirac particles, neither quarks nor leptons. Such particles have not been seen. However, astrophysicists see indirect evidence that at least ten times as much matter exists in the universe than has been observed with our optical and radio telescopes. For instance, stars somewhat beyond the edge of the Milky Way circle our galaxy at surprisingly high speeds, indicating that they are being gravitationally pulled toward the center of the galaxy by much more matter than is visible to our instruments. The **6s**, **10s**, and so on predicted by my model might be the source of this so-called “dark matter.”

I have indicated how one generation of quarks and leptons can be generated by a harmonic-oscillator force acting on weak-isospin doublets. However, there are two more families to be accounted for. As I mentioned earlier, these can be generated by increasing the number of extra dimensions from three to four. A symmetric harmonic-oscillator well in *four* dimensions will yield $SU(4)$ multiplets with multiplicities **1**, **4**, **10**, . . . In an $SU(4) = SU(3) \times U(1)$ de-

composition, the **1** stays a **1**, the **4** breaks up into a **1** plus a **3**, the **10** breaks up into a **1** plus a **3** plus a **6**, etc. This results in the *weight diagrams* shown in Figure 16. Quarks and leptons suggested by these quantum numbers are indicated.

In Figure 16, the quantum numbers, $\tilde{N} = 0, 1, 2$, correspond to increasing mass levels. The chart is divided into two halves, with the weight diagrams on the left corresponding to particles with weak-isospin quantum number $\tilde{m}_{\tilde{S}} = 1/2$ (isospin “up”) and the diagrams on the right to particles with weak-isospin $\tilde{m}_{\tilde{S}} = -1/2$ (isospin “down”). If the restraining force is that of a pure harmonic oscillator, then the multiplets go on past to $\tilde{N} = 2$ infinity.

I have calculated these particle multiplets using a quantum-mechanical Dirac equation in eight dimensions with a symmetrical harmonic-oscillator potential acting in the four extra dimensions (Bryan, 1998, 1999). The equation separates into two equations, a standard free-particle Dirac equation operating in ordinary four-dimensional space-time and a second Dirac equation acting in the four extra dimensions. An extremely large mass, M_0 (not any particle’s rest mass), is added to the potential so that the Dirac equation in the extra four dimensions reduces approximately to a type of Schrödinger equation. This is used to predict the particles noted in Figure 16.

Now some caveats: The Dirac equation of my model does not quite preserve $SU(4)$ symmetry, or the $SU(3)$ symmetry of the quarks, so it does not agree

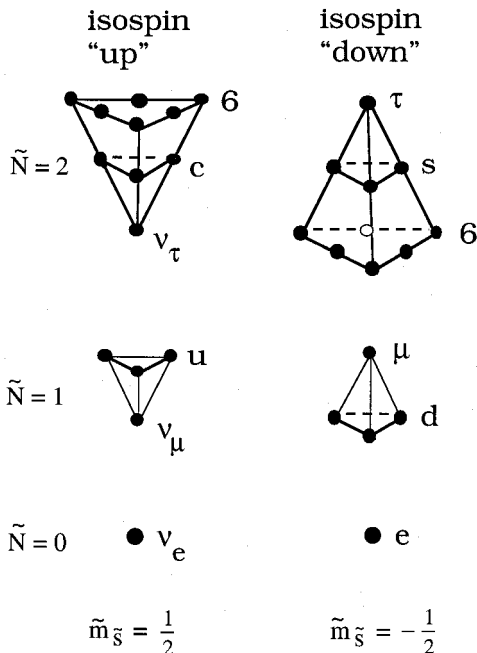


Fig. 16. $SU(4)$ multiplets generated by a symmetrical harmonic-oscillator well acting in a Schrödinger equation in four flat extra dimensions.

perfectly with Quantum Chromodynamics. Also, as can be seen in Figure 15, the model predicts masses rising at a constant rate, whereas experimentally, particles' masses seem to increase exponentially, as in Figure 3. However, "Higgs-Yukawa" terms might perhaps be introduced to generate the correct masses, as is done in the Standard Model. [The Standard Model is a gauge field theory, which fits all of the known elementary-particle data with some 19 adjustable constants. It was invented by Sheldon Glashow (1961), Steven Weinberg (1967), and Abdus Salam (1968). For a less technical description of the Standard Model, see Coughlan and Dodd (1991) and references listed therein.]

There are two general classes of particles in nature, the Dirac particles (and their antiparticles) that I have been describing, and bosons. The W^+ , W^- , Z^0 , and photon are bosons, plotted along with the Dirac particles in Figure 3. They mediate the forces between the Dirac particles. My model treats Dirac particles as real particles but only takes bosons in account when they interact with Dirac particles. Work is underway to include bosons as real dynamical entities.

There has to be a mechanism to keep the particles in place in the extra dimensions, so they do not drift off and disappear from our universe. In most models, localizing poses no problem because the assumed extra dimensions are tiny circles or generalizations of circles of the order of 10^{-34} m in diameter, so the particles have hardly any place to go. However, in models with infinitely extended extra dimensions, such as mine, some trapping mechanism has to exist. For the time being, I simply introduce a potential well "by hand" to trap the particles. However, in 1983 Rubakov and Shaposhnikov had already considered the possibility that the extra dimensions might be infinite in extent, and they solved the particle-trapping problem with an elegant mechanism, namely a soliton, generated by the nonlinear field equations of their model (Rubakov and Shaposhnikov, 1983). However, they only considered the case of a single extra dimension. For this case, they trapped a boson in the well \tilde{V} , sketched in Figure 17.

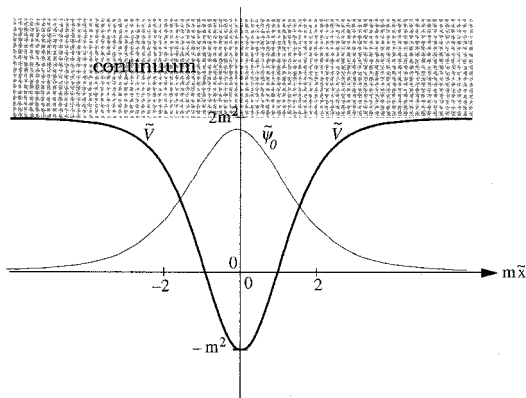


Fig. 17. Potential well \tilde{V} in one extra dimension generated by soliton (kink) in ϕ^4 theory; wave function of Dirac particle trapped on the soliton is denoted $\tilde{\psi}_0$.

The width of the well is determined by the mass parameter, m . Note that the well does not rise indefinitely, but only as high as $2m^2$. This particular well traps just one kind of particle, at the level $\frac{3}{2}m^2$. Particles whose mass-squared exceeds $2m^2$ lie in the continuum and can propagate freely in Rubakov and Shaposhnikov's extra dimension \tilde{x} .

If the Rubakov–Shaposhnikov model could be extended from the one extra dimension to four extra dimensions, then it might provide the entrapment that I have simulated with the harmonic-oscillator well. Furthermore, a Rubakov–Shaposhnikov-type well would provide a physically natural way to limit the number of generations to just the three that have been seen, because the well rises only a finite amount. Particles with energies exceeding the top of the well would travel freely in all eight dimensions and would not be listed in Figure 3.

3. Some Speculations

I have outlined a model based on four extra dimensions stretching out to infinity, in addition to the usual four dimensions of space and time (Bryan, 1998, 1999). The quarks and leptons in this picture are nevertheless trapped in a very small region in these extra dimensions, about 10^{-19} m in diameter (which also happens to be the upper limit of the size of the electron in ordinary space). Presumably I could modify the model so that the extra dimensions themselves were little circles 10^{-19} m in diameter. However, the mathematics is much simpler if the extra dimensions stretch out indefinitely, and so, by Occam's razor, I choose such a model. ("The upper dimensions are just like the lower dimensions.") But if the extra dimensions do stretch out to infinity, then why haven't we seen them? Well, perhaps some of us have. It may be that some of the people who have had an out-of-body experience (Monroe, 1971) or an NDE (Moody, 1975) have seen and perhaps traveled into the extra dimensions.

If we take ordinary space-time and reduce it to just one spacelike dimension, z , as in Figure 6, and then take the four extra dimensions of my model and reduce them to two extra dimensions, say \tilde{x} and \tilde{y} , then the particles are trapped in a kind of tube in both the ordinary and the extra dimensions, as illustrated in Figure 18. The particles are free to move back and forth along the z

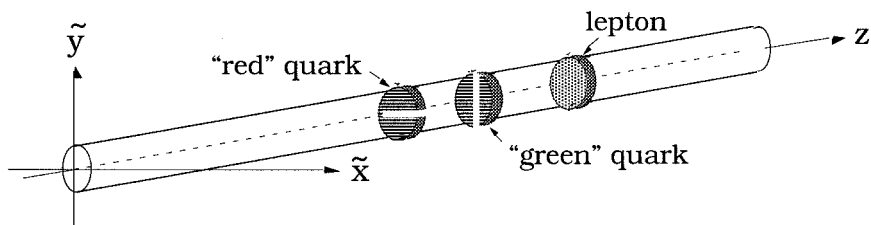


Fig. 18. Eight-dimensional space-time reduced to one ordinary dimension (z) and two extra dimensions (\tilde{x} and \tilde{y}); quarks and leptons are shown as quantum-mechanical wave packets, trapped in a harmonic-oscillator well in the \tilde{x} and \tilde{y} dimensions.

axis but are constrained by the walls of the tube (representing the harmonic-oscillator well) from going off in the \tilde{x} or \tilde{y} direction. Because we are made of quarks and leptons, we are also trapped in the tube according to this model. In one real dimension, we might be represented by the string of quarks and leptons, as illustrated in Figure 19.

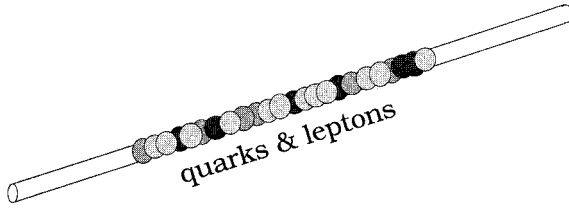


Fig. 19. Human body depicted as a string of quarks and leptons in one ordinary dimension, confined in a tube in two extra dimensions.

On the other hand, our consciences may not be trapped in the tube and perhaps are not fundamentally constrained at all (Roberts, 1972), as suggested by Figure 20. [For an interesting article that hints how a consciousness might control a physical body using energies no greater than those of visible photons (of the order of electron volts), see Firsoff (1975).]

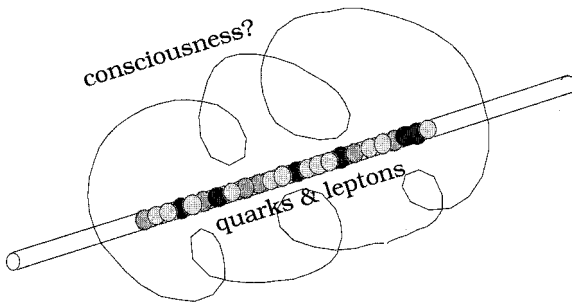


Fig. 20. Human consciousness sketched as a kind of wave function, not necessarily confined to human body (depicted in one dimension as a string of quarks and leptons).

Now, if there is one tube representing our universe, then there is probably another tube somewhere else representing another universe. There might be an uncountable number of tubes, or universes. Perhaps one of the other tubes is very close to our tube. Then a “tunnel” might make it possible for a human consciousness to drift over to the other tube, and so entering, see a whole new universe. This is illustrated in Figure 21. Perhaps upon entering the other universe, the consciousness encounters the “light” and other consciences

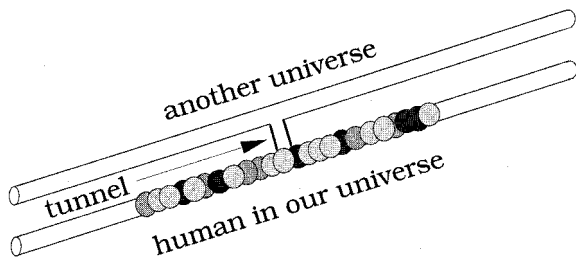


Fig. 21. Tunnel facilitating departure of human consciousness from our universe to another universe in higher dimensional space-time.

(Moody, 1975). The other universe need not have the same number of dimensions as our universe, and particles there could be pure energy without mass.

As I mentioned earlier, if a particle has sufficient energy, then it might escape our universe (the tube) and propagate freely in all of the dimensions, ordinary and extraordinary. For example, if an electron and a positron were each accelerated to sufficiently high energies in a linear accelerator, then upon colliding they might escape the tube. This is illustrated in Figure 22. Perhaps the next generation of accelerators, in particular the LHC proton accelerator, being constructed at CERN in Geneva, Switzerland, will be able to accelerate particles to sufficiently high energies to escape.

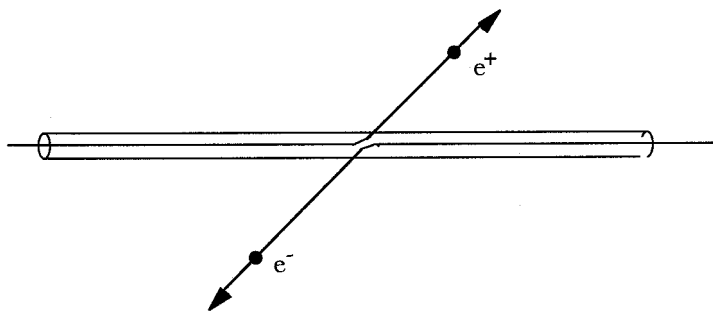


Fig. 22. Electron (e^-) and positron (e^+) accelerated in linear accelerator to sufficiently high energies to escape our universe and travel in the extra dimensions.

It may well be that if there are indeed long extra dimensions, then particles abound in that space. Probably they can bind to one another, just as particles in our four-dimensional space-time can bind to one another. If such particles exist, then perhaps they can be fashioned into UFOs. The UFOs would not be able to actually enter our space, as they would probably blow up upon falling into our "potential well." However, they might be able to approach very closely (perhaps even as close as a millimeter). Associated consciousnesses might

easily penetrate our space then. This might be the basis for reports of alien abduction (Mack, 1994).

Finally, information might be able to propagate in ways not possible in ordinary space-time. For example, ordinary electromagnetic signals sent from submarines are quickly absorbed by the sea water, but if another kind of signal could be sent through the wall of our “tube” into the extra dimensions, then the signal might propagate quite freely in these higher dimensions, to finally return to a receiver somewhere else within our tube (Targ and Puthoff, 1977). This is illustrated in Figure 23.

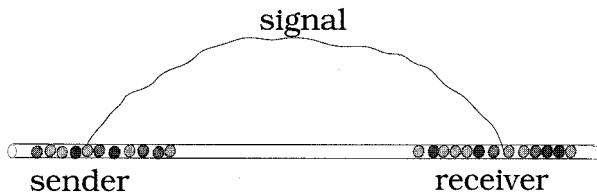


Fig. 23. Signal leaving sender in ordinary space-time, travelling through higher dimensions and returning to receiver in ordinary space-time.

3.1. Note Added

Recently there has been considerable interest in the possibility that the extra dimensions, although not flat or infinite in extent, might still be circles of millimeter size. Only gravity waves would range that far out. All other particles would be confined to distances of the order of 10^{-34} m in the extra dimensions. Arkani-Hamed, Dimopoulos, and Dvali (1998) and Antoniadis *et al.* (1998) have proposed models of this sort. These models have passed a gauntlet of tests but many challenges remain. See, for example, Banks, Dine, and Nelson (1999).

Acknowledgments

I would like to thank Hal Puthoff and Robert Butts for much encouragement over the years. I would also like to thank Robert Monroe and John Mack for useful conversations, and Sunny Nash for helpful criticism.

References

- Antoniadis, I., Arkani-Hamed, N., Dimopoulos, S., & Dvali, G. (1998). New dimensions at a millimeter to a fermi and superstrings at a TeV. *Physics Letters B*, 436, 257.
- Arkani-Hamed, N., Dimopoulos, S., & Dvali, G. (1998). The hierarchy problem and new dimensions at a millimeter. *Physics Letters B*, 429, 263.
- Banks, T., Dine, M., & Nelson, A. E. (1999). Constraints on theories with large extra dimensions. *Journal of High Energy Physics* (electronic journal), 06(1999), 014.
- Bryan, R. A. (1998). Are quarks and leptons dynamically confined in four flat extra dimensions? *Nuclear Physics B*, 523, 232.

- Bryan, R. A. (1999). Are the Dirac particles of the Standard Model dynamically confined states in a higher dimensional flat space? *Canadian Journal of Physics*, 77, 197 (hep-ph/9904218).
- Coughlan, G. D., & Dodd, J. E. (1991). *The ideas of particle physics: An introduction for scientists*. Cambridge, UK: Cambridge University Press.
- Firsoff, V. A. (1975). Life and quantum physics. In Oteri, Laura (Ed.), *Quantum physics and parapsychology* (p. 109). New York: Parapsychology Foundation.
- Glashow, S. L. (1961). Partial-symmetries of weak interactions. *Nuclear Physics*, 22, 579.
- Lee, H. C. (Ed.). (1984). *An introduction to Kaluza-Klein theories*. Singapore: World Scientific.
- Mack, J. E. (1994). *Abduction: Human encounters with aliens*. New York: Scribner's.
- Miller, J. G. (1980). Kaluza and Klein's five-dimensional relativity. In Marlow, A. R. (Ed.), *Quantum theory and gravitation* (p. 221). New York: Academic Press.
- Monroe, R. A. (1971). *Journeys out of the body*. New York: Doubleday.
- Moody, R. A., Jr. (1975). *Life after life*. Atlanta, GA: Mockingbird.
- Particle Data Group (1998). Review of particle physics. *European Physical Journal C*, 3, 1.
- Roberts, Jane (1972). *Seth speaks: The eternal validity of the soul*. Englewood Cliffs, NJ: Prentice-Hall.
- Rubakov, V. A., & Shaposhnikov, M. E. (1983). Do we live inside a domain wall? *Physics Letters B*, 125, 136.
- Salam, A. (1968). Weak and electromagnetic interactions. In Svartholm, N. (Ed.), *Elementary particle theory: Relativistic groups and analyticity* (pp. 367-377). Stockholm: Almqvist & Wiksell.
- Targ, R., & Puthoff, H. (1977). *Mind-Reach: Scientists look at psychic ability*. New York: Dell.
- Weinberg, S. (1967). A model of leptons. *Physical Review Letters*, 19, 1264.