A Mechanism for Accelerated Radioactive Decay

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Abstract

Kaluza-Klein theory, originally proposed in 1921 to 1926, has been described as a miraculous synthesis of Einstein's gravitation theory with Maxwell's equations of electricity and magnetism. In an approach which anticipated modern string theory, Kaluza and Klein added a fifth dimension of space to the three familiar spatial dimensions and one time dimension. The extension of Einstein's theory to this fifth dimension then led naturally to Maxwell's equations. The theory also naturally leads to a relation between the constant G of Newton's law of gravitation and the fine structure constant $\alpha = e^2/\hbar c$. This relation depends on the circumference of the compactified fifth dimension, so that variation in this circumference over the history of the universe could be viewed as variation in physical constants, such as the fine structure constant. If, during early creation week, say before the creation of man, such variations were to occur, they could lead to accelerated nuclear decay, thus adjusting isotopic abundances, without giving humans an unacceptable dose of radiation.

Introduction

Undergraduate students of physics often have never heard of the Kaluza-Klein theory. While the nuclear forces were unknown until the 1930's, physicists nevertheless were trying to unify the known forces of physics, electromagnetism and gravity, in one theory. Hermann Weyl had investigated one such theory prior to 1921 (Chaffin, 1986). Kaluza (1921) and Klein (1926a,b) worked on another somewhat successful theory which regarded the universe as having an extra fifth dimension besides the usual three space plus one time dimensions. Kaluza was a contemporary of Albert Einstein, and in fact Kaluza's paper on this subject was presented to the Prussian Scientific Academy in Berlin by Einstein himself. Klein, at the time he did his original work on this subject, was at the Niels Bohr Institute in Copenhagen as well as at the University of Michigan, Ann Arbor. English translations of the original German articles of Kaluza and Klein have been published in Sabbata and Schmutzer (1983) and Appelquist, Chodos, and Freund (1987). While Kaluza required that physical quantities of ordinary spacetime should have zero or vanishingly small derivatives with respect to the fifth coordinate, Klein wanted to replace this assumption by the requirement that physical quantities be periodic with respect to this coordinate. This is equivalent to the condition that the fifth dimension is "rolled up." The metric components (the doubly-subscripted quantities used to specify the geometry in general relativity theory) connecting the fifth coordinate to the four coordinates of the usual spacetime are interpreted as the potential and the three components of the vector potential of electromagnetic theory. The amazing result is that the field equations for these potentials reduce to the usual Maxwell equations. While early work on this approach essentially ran into a dead end (Einstein and Bergman, 1938; Jordan, 1947; Bergman, 1948), modern superstring theories may be viewed as extensions of the Kaluza-Klein idea (Witten, 1981; Weinberg, 1983; Thomsen, 1984; Kolb, Perry, and Walker, 1986), and enthusiasm is running high (Chown, 1998; Raiford, 1999). It may be that the Kaluza-Klein theory will soon become much better known to physics students.

How could a dimension be viewed as "rolled up"? One must first realize that in general relativity theory, the presence of matter causes a curvature of space (Figure 1). This curvature is a "curvature" of four dimensional spacetime. But visualization is aided by suppressing all but two space dimensions and the time dimensions. Then the curvature can be regarded as positive when it like the surface of a sphere or negative when it is like a saddle shape. The fifth dimension's "rolling up" is a description of the topology of the model being proposed (Figure 2). If a long piece of paper is rolled up and two edges glued together, one gets a cylinder. If we imagine two dimensional beings who can only move and see inside the two dimensional surface thus formed, one gets the idea of this curvature. In superstring

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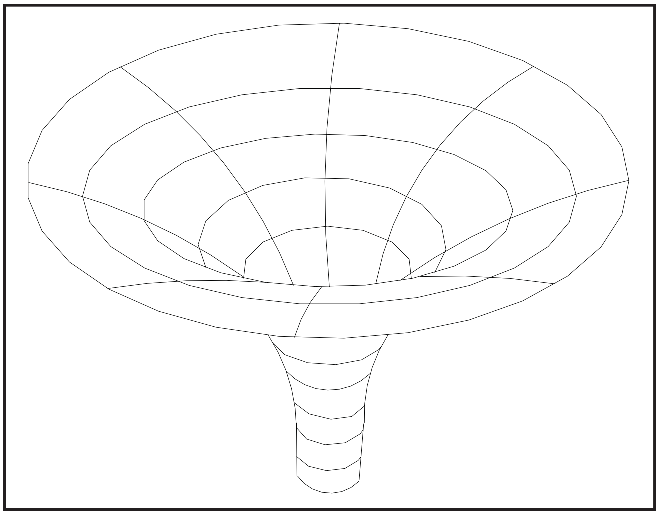

Figure 1. A two dimensional space with curvature caused by the presence of a large mass.

theory there are six or more finitely long dimensions which are "rolled up." In the simplified Kaluza-Klein idea, there is only one rolled up dimension. Mathematicians call an object with the topology of a circle as S^1. The cylinder is then the *direct product space* RxS^1, where R is the topology of a straight, infinite line. Then our universe, according to the Kaluza-Klein idea, and assuming that spacetime is "flat," is the direct product of three spatial R's, one time coordinate R, and the S^1.

Biblical evidence, when interpreted straightforwardly according to the original meanings of the language in which the Bible was written, points toward an earth with an age measured in thousands rather than millions or billions of years. On the other hand, scientific evidence from radioisotopes seems at first sight to indicate a history of billions of years of radioactive decay, if half lives have been relatively constant over the history of our world. Hence, scientists who believe the biblical creation account have wondered from time to time whether half lives and the associated decay "constants" might not be "constants" but variables (Chaffin, 1994). The purpose of this paper is to initially examine the Kaluza-Klein idea to see if it might provide a useful model in this regard. Besides the usual references, a bibliography of relevant literature is provided to assist in this venture.

The Relation Between G and α

Although Klein (1926a,b) had the essential equations in his early papers, the relationship between G and α was most clearly explained by Souriau (1963). It has been noted by various authors in recent years, for example Li and Gott (1998), Salam (1989, p. 487), Marciano (1984), Appelquist and Chodos (1983), Freund (1982) and Chodos and Detweiler (1980). Souriau began with the linear invariant equation in five dimensions:

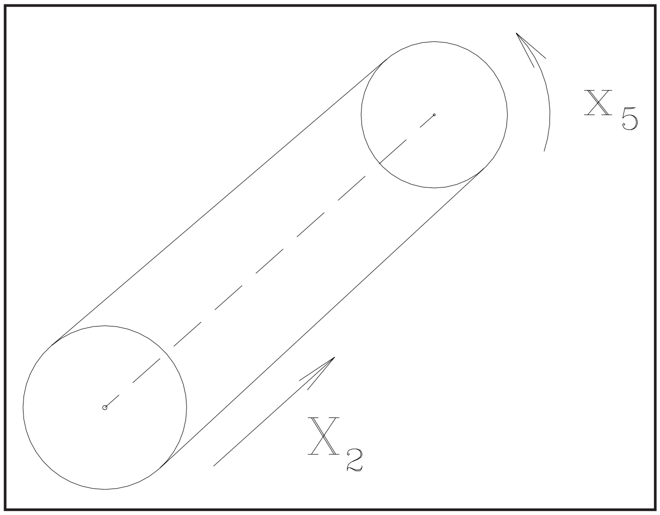

Figure 2. A rolled up dimension added to a flat dimension forms a cylinder as shown. The values of x^5 and $x^5 + b$, where b is the circumference $2\pi r(g_{55})^{1/2}$, are identified as the same point.

$$D_5\varphi + a\varphi = 0 \tag{1}$$

where D_5 is the d'Alembertian in five dimensions, φ denotes a real wave function, and a is a real constant. The four dimensional version of this equation is know in quantum physics as the Klein-Gordon equation (Kragh, 1984), and is applied to particles of spin zero. In a curved spacetime, the constant "a" could include a contribution from the Riemannian curvature scalar R (Anderson, 1971; Bicknell, 1976; Penrose and Rindler, 1984, Vol. 2, p. 369), but Souriau restricted his considerations to the case where it does not.

The quantity $D_5\varphi$ is given by (Adler, Bazin, and Schiffer, 1965, p. 75):

$$D_5\varphi = \frac{1}{\sqrt{|g|}}\frac{\partial}{\partial x^i}\left[\sqrt{|g|}\,g^{ik}\,\frac{\partial}{\partial x^k}\varphi\right]. \tag{2}$$

Choosing the coordinate of the compactified fifth dimension so that it varies from 0 to 2π, then the wavefunction φ has the period 2π in the fifth-dimension coordinate x^5, we can then expand j in a Fourier series

$$\varphi = \sum_Z \varphi_Z e^{[iZx^5]} \tag{3}$$

where Z denotes either a positive, negative or zero integer, the φ_Z are complex functions of x^μ , φ_Z and φ_{-Z} are complex conjugates, and φ_0 is real. We next make the approximation that the gravitational field is small and the motion is not relativistic, then the metric tensor is reduced to the metric of a flat spacetime of four dimensions plus the "rolled-up" fifth dimension. Furthermore, according to the Kaluza-Klein results (Kaluza, 1921; Klein, 1926a;

Souriau, 1963, p. 572) the $g^{\mu 5}$ components are related to the electromagnetic vector potential A^{μ} via the equation

$$g^{\mu 5} = -\frac{1}{\xi}\sqrt{2\chi}A^{\mu} \qquad (4)$$

[In order to conform to the usual definition of the vector potential as in Klein (1926) and Chodos and Detweiler (1980), I multiply Souriau's vector potential by a factor of $1/\sqrt{(4\pi)}$.] and the g^{55} component is given by

$$g^{55} = \frac{1}{\xi^2}\left[-1 + 2\chi A_{\mu}A^{\mu}\right] \qquad (5)$$

where χ is the universal gravitation constant and ξ is the "radius of the cylinder" for the fifth dimension.

At this point Souriau introduced what he called *the transverse variables*. These variables are defined as shown in Figure 3. To describe the five dimensional view of the universe U, we consider functions or *maps* which map the five coordinates x^1, x^2, x^3, x^4, and x^5, to a point M of U. *Standard maps* are defined to be those for which x^5 has the period 2π, and they are the only ones we use. M being a point of U, a *fibre* M passing through M is the closed curve obtained when x^5 alone varies (see Figure 3). Then the set of these fibres is denoted U, and this set is interpreted as the "points" of ordinary space time. Now for each *standard map* we define a corresponding map which is *transverse*, which means that the fibres are orthogonal to the hypersurfaces x^5 = constant. In terms of these *transverse variables* defining this map, we have for the determinant of the metric as related to the metric determinant for transverse variables:

$$|g| = \xi^2\left|\tilde{g}\right|, \qquad (6)$$

and for the metric components related to the metric components for transverse variables:

$$g^{\mu\nu} = \tilde{g}^{\mu\nu}. \qquad (7)$$

Armed with these equations we reduce the five dimensional Klein-Gordon equation to:

$$\tilde{g}^{\mu\nu}\left[\frac{\partial}{\partial x^{\mu}} - \frac{iqA_{\mu}}{\hbar}\right]\left[\frac{\partial}{\partial x^{\nu}} - \frac{iqA_{\nu}}{\hbar}\right]\varphi_z + \frac{m^2}{\hbar^2}\varphi_z = 0 \qquad (8)$$

which is the Klein-Gordon equation for a particle of spin zero in an electromagnetic field, where the mass m and charge q are given by:

$$m = \hbar\sqrt{\frac{Z^2}{\xi^2} + a}\,, \qquad (9)$$

and

$$q = \frac{Z}{\xi}\sqrt{2\chi}\hbar\,. \qquad (10)$$

The first equation, when combined with numerical values, shows that the mass of the Z=2 excitation is more than 10^{20} MeV above that of the Z=1, so particles of that energy are of too great an energy to be observed. We can only observe the Z=1 case, where the charge is the elementary unit e. The second equation gives the charge q of the particle in terms of the universal gravitation constant $\chi = 8\pi G/c^2$ and the radius ξ of the fifth dimension. Solving for ξ gives

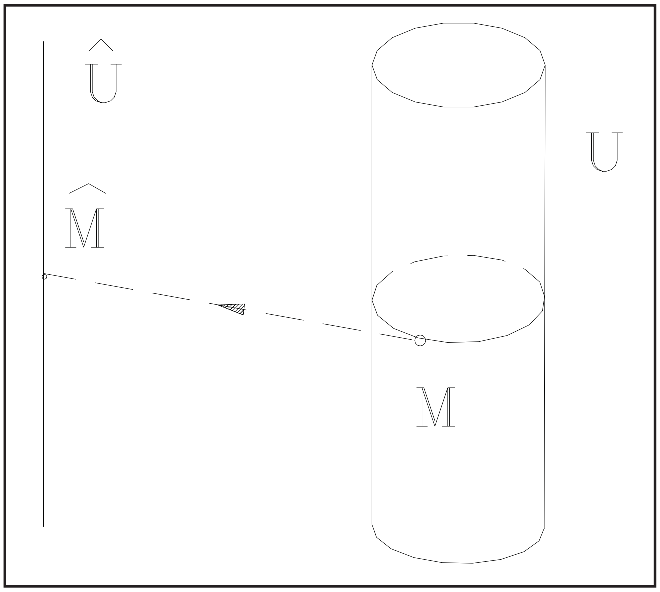

Figure 3. (After Souriau's Figure 1) Illustration of the map of points M to points of the usual spacetime.

$$\xi = \frac{\hbar}{ec}\sqrt{16\pi G} = 1.341x10^{-31}\,cm. \qquad (11)$$

We are using electrostatic units here (Purcell, 1985). The size of an atomic nucleus is of the order of 10^{-13} cm, so this length is much smaller than the size of an elementary particle, giving credibility to the idea that the fifth dimension is "rolled up" to a negligible size.

Having derived these relations, we would now like to relate them back to the accelerated decay problem that started this exercise. As I pointed out in Chaffin (1994), only variations of dimensionless combinations of "constants" are physically meaningful. Theories which have variation while keeping all dimensionless ratios constant are physically trivial, amounting only to a continual redefinition of units over time. One such *dimensionless ratio* is the *fine structure constant* $\alpha = e^2/\hbar c$. In terms of α the relation just derived can be written

$$\alpha = \frac{16\pi\hbar G}{\xi^2 c^3} \qquad (12)$$

Both sides of this equation are dimensionless. A variation in the radius ξ thus could mean a variation of the fine structure constant while the gravitational constant, Planck's constant, and the speed of light c remain the same. Supposing the radius and circumference of the fifth dimension were larger at times early in creation week, one might expect nuclei to decay at an increased rate due to the smaller fine structure constant, amounting to a smaller Coulomb barrier for alpha decay (See Chaffin, 1994, for a model which could be adapted to this situation.). Of course, beta decay would also be affected. If the variation were over by the time of the creation of man, then life would not be subject to increased radiation doses.

Explaining the Isotopic Distributions of Uranium

Uranium isotopes U-238, U-235, and U-234 occur in the per cent abundances 99.27, 0.72, and 0.0055%, with other isotopes only occurring in trace amounts. The half lives of these isotopes are 4.47×10^9 years for U-238, 7.04×10^8 years for U-235, and 2.47×10^5 years for U-234. A condition known as *radioactive equilibrium* occurs when the ratios of the abundance to the half lives of successive members of a decay chain are equal. The most probable decay mode of U-238 is alpha decay, which produces Th-234. Thorium-234 undergoes beta minus decay with a half life of 24.1 days, producing Protactinium-234. Pa-234 then also undergoes beta minus decay with a half life of 6.69 hours producing Uranium-234. Thus U-234 is in the decay chain of U-238, and radioactive equilibrium does exist because 0.0055 divided by the half life of U-234 is the same as 99.27 divided by the half life of U-238, roughly 2.2×10^{-8}. The two ratios are equal to within the uncertainties in the data. Kofahl and Seagraves (1975, p. 201) documented cases where radioactive disequilibrium exists in some samples, but the departures are relatively small. The variations may possibly be explained in terms of the difference in relative solubility of U-234 and U-238 starting from hexavalent and tetravalent uranium in compounds and their decomposition products (Chalov and Merkulova, 1968). For an earth of only some thousands of years old, it is difficult to explain the bulk of the approximately equal, 2.2×10^{-8}, ratios without an episode of accelerated decay. Starting from an arbitrary initial state, it takes only a few half lives of U-234 to establish equilibrium, implying an age of the samples of at least several hundred thousand years. To justify the young earth viewpoint, it is logically correct that the rocks may have been created already in this state of equilibrium, with no time needed to reach that state. However, a more natural explanation seems to be provided by accelerated radioactive decay. We do not know the original ratio of U-234 to U-238 in the created materials of the early earth, but if we assume that they were of the same order of magnitude, then a period of accelerated decay would adjust this ratio to the 0.0055 ratio presently found in the bulk of earth materials. This seems to be evidence that such accelerated decay did, in fact, occur (Heinze, 1992).

The U-235 abundance, compared to U-238, also seems to support this point of view. If the initial abundances of these two isotopes were of the same order of magnitude, then several half lives of U-235 are needed to establish the present 0.72% and 99.27% isotopic abundances, implying sample ages of millions of years. To avoid this conclusion without accelerated decay, one seems forced to assume that the uranium isotopes were created in isotopic per cent abundances approximating those necessary for radioactive equilibrium.

The Vacuum Is Not Empty

Part of the reason that Einstein and others worked on the Kaluza-Klein theory was motivated by the thought that the fifth dimension might provide the hidden variables that could eliminate the indeterminacy from quantum mechanics (Einstein, Rosen, and Podolsky, 1935). When the 1920's discovery of quantum mechanics was over, the classical laws were superseded by quantum laws based on the uncertainty principle. The quantum theory allows energy to appear out of nothing, in the form of pairs of virtual particles, such as electrons and positrons, as long as the virtual pairs annihilate within a small time interval given by the uncertainty principle. The vacuum, or "empty" space, is filled with pairs of virtual particles and antiparticles appearing, moving apart, and coming back together to annihilate each other. Theory allows energy density to be negative in some places, so that the total energy remains positive. There are measurable consequences of this concept, one of which is called the *Casimir effect* (Casimir, 1948; Casimir and Polder, 1948). Imagine two parallel metal plates a short distance apart. Hawking (1996, pp. 164-165) described the action between the plates as follows:

> The plates will act like mirrors for the virtual photons or particles of light. In fact they will form a cavity between them, a bit like an organ pipe that will resonate only at certain notes. This means that virtual photons can occur in the space between the plates only if their wavelengths (the distance between the crest of one wave an the next) fit a whole number of times into the gap between the plates. If the width of a cavity is a whole number of wavelengths plus a fraction of a wavelength, then after some reflections backward and forward between the plates, the crests of one wave will coincide with the troughs of another and the waves will cancel out.

Because the virtual photons between the plates can have the resonant wavelengths, there will be slightly fewer of them than in the region outside the plates where the virtual photons can have any wavelength. Thus there will be slightly fewer virtual photons hitting the inside surfaces of the plates than the outside surfaces. One would therefore expect a force on the plates, pushing them toward each other. This force has actually been detected and has the predicted value. Thus we have experimental evidence that virtual particles exist and have real effects.

Hawking then goes on to say that these effects mean that there is a negative energy density between the plates. This so-called Casimir effect has recently been measured in the laboratory (Lamoreaux, 1997; Raiford, 1999). The assignment of these properties to the vacuum is part of the rationale for unified field theories, including multi-dimensional string theory. At some point in the early history of the universe, the extra dimensions "roll up" leaving only three space plus one time dimensions.

Gauge Fields and Extra Dimensions

Witten (1981) discussed the possibilities of extending Kaluza-Klein theory to 4+n dimensions. Our ordinary spacetime is sometimes referred to as Minkowski space, M^4. The present ground state of the universe is described in terms of the combination of Minkowski space M^4 and a compact space B of dimension n, the so called *direct product space* M^4xB. Witten considered the *symmetry group* SU(3)xSU(2)xU(1) which describes the standard model of particle physics, the electroweak theory plus quantum chromodynamics. The compact group B needs to therefore correspond to a space which the group SU(3)xSU(2)xU(1) could act. This restricts the dimensions of B to at least seven, implying the universe had at least eleven dimensions. Although all possible theories have not been explored yet, Witten stated that " . . . the most serious obstacle to a realistic model of the type considered in this paper is that the fermion quantum numbers do not turn out right." (Witten, 1981, p. 426).

Marciano (1984) constructed a model which related not only the fine structure constant, but also the coupling constants of electroweak and quark-gluon models to the size of the n extra dimensions. While his "model" is not the only possible one, his conclusion may extend to other cases also. Marciano posed the question: "Are extra dimensions a physical reality or merely a model-building mathematical tool?"

Conclusions

Recently Webb et al. (1999) reported evidence for a variation in the fine structure constant between nearby matter and matter in gas clouds seen in absorption against background quasars. Quasars with high redshifts presumably are quasars which were young, at the time of emission, compared to nearby matter. For quasars with redshifts in the range from 1 to 1.6 (the highest range analyzed thus far), the data presented by Webb et al. seems to give evidence for a slightly smaller fine structure constant than the value in nearby matter. However, the difference is small and it is possible that future work will uncover systematic errors in the observations.

Whether or not the future bears out Webb et al.'s findings, there is room for study of the possible variations of physical constants other then the fine structure constant. It may be that the fine structure constant was constant but some of the coupling constants involved in nuclear decay were not (Chaffin, 1994). Whether or not the extra dimensions really exist, the theory of fundamental decay processes is far from complete. Hence, the possibility of accelerated decay during earth history is real.

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Appendix
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Once positivism destroyed Judeo-Christian consciousness, individuals were open "to respiritualization from non-Christian sources" that included such radical political ideologies as nationalism, humanitarianism, biologism, and psychologism.

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