The Trouble with Spacetime:
The Rise of the Planck Length,
The Fall of a System of Theory,
and
What Comes Next

Abstract

In ancient times, the incommensurability of discrete numbers, and continuous physical magnitudes, destroyed the Pythagorean cult. Now, in modern times, the incompatibility of the discrete theory of matter, and the continuous theory of spacetime, vexes, if not threatens, the theoretical community with a similar fate. With the rise of string theory, hopes of reconciling quantum physics with continuous physics arose, only to inflate into a Landscape of near infinite possibilities and, with that, the prospect of describing the physical laws of a unique, predictable, universe, diminished significantly. Even worse, our very notion of space now appears to "evaporate," at the Planck length, leading to the conclusion that both space and time, as we know them today, are "doomed," as fundamental entities of theoretical physics. Since no one yet knows how to do physics without time, we reexamine Einstein's notion of spacetime, specifically the dimension of time in spacetime, in the light of an old algebra, once proposed, as the basis for the science of pure time.

The most relevant message of Lee Smolin's book[1] is not the alleged failure of string theory, but the fundamental crisis in theoretical physics, which the pursuit of string theory seems to have only exacerbated. Smolin and others, like Peter Woit, author of another anti-string theory book[2] are worried that, based on ideas coming from string theory research, physicists are abandoning hope that a unique, unified, solution to fundamental challenges in theoretical physics actually exists.

Even though at least one prominent physicist regards these two books as "silly,"[3] they have nevertheless managed to capture a lot of media attention and focused the public's mind on the fundamental crisis in theoretical physics. The roots of the crisis go back to the beginnings of modern science, to two inventions of the human mind, the real numbers corresponding to the linear continuum of physical magnitudes, and the complex numbers of size one, corresponding to the rotational continuum of physical magnitudes, two important inventions that are hailed as great milestones in the advancement of civilization, and rightly so. The modern theories of the continuum are embodied in the principles of classical mechanics, based on the invention of irrational numbers, via the mathematics of calculus, the most erudite and exotic form of which is found in Einstein's theory of general relativity (GR), while the modern theories of the discretium are embodied in the principles of quantum mechanics, based on the invention of complex numbers, via the mathematics of group theory, where the ultimate achievement is the standard model (SM) of particle theory.

Consequently, mankind is left with two theories, one in which the physics is continuous in nature, the other discrete, and the trouble with these two physical theories is that they are fundamentally incompatible with each other. Moreover, the hope of completely reconciling

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[1] Lee Smolin, *The Trouble with Physics: The Rise of String Theory, The Fall of a Science, and What Comes Next*, Houghton Mifflin, 2006

[2] Peter Woit, *Not Even Wrong, The Failure of String Theory and the Search for Unity in Physical Law,* Basic Books, 2006

[3] David Gross, cited on The Reference Frame

them in string theory grows fainter in the minds of some, while the seemingly futile, ongoing, attempt to achieve success continues to soak up the vast majority of the theoretical community's manpower and resources.

Recently, Lee Smolin and Brian Green, a popular string theorist, and colleague of Woit's, discussed the trouble with physics with Ira Flatow, the host of the NPR series, *Science Friday*.[4] Though they differ on the proposition of string theory, they agree that physics, based on the familiar concepts of space and time, is no longer tenable in certain realms. They think these notions must "evaporate."

The reason physicists think that traditional space and time concepts might "evaporate," or that they are "doomed," as fundamental entities, as Ed Witten[5] describes it, is because, in string theory, the dimensions and/or the topology of the spacetime continuum can be changed in a way that implies that space cannot be fundamental, but must be emergent. String theory studies also indicate that there is no operational meaning to distances smaller than the Planck length, due to the Heisenberg uncertainty principle, and since 3D space and 1D time are joined together in 4D spacetime, in modern theoretical physics, if space is emergent, then this implies that time must be emergent also.

But as David Gross exclaims,[6] no one knows how to do physics without time. He succinctly captures the dilemma in the rewording of an ancient verse that he recites: "By convention there is space, by convention there is time, but in reality there is…?" Then he laments, "The problem is that I don't know how to finish the verse." On another occasion, he observes:

> Everyone in string theory is convinced...that spacetime is doomed. But we don't know what it's replaced by. We have an enormous amount of evidence that *space* is doomed. We even have examples, mathematically well-defined examples, where space is an emergent concept.... But in my opinion the tough problem that has not yet been faced up to at all is, "How do we imagine a dynamical theory of physics in which *time* is emergent?" ...All the examples we have do *not* have an emergent time. They have emergent space but not time. It is very hard for me to imagine a formulation of physics without time as a primary concept because physics is typically thought of as predicting the future given the past. We have unitary time evolution. How could we have a theory of physics where we start with something in which time is never mentioned? [7]

In contemplating the implications of this daunting dilemma, one's thoughts naturally turn to the meaning of the mysterious relation of mathematics and physics, something that is still not well understood even after centuries of intellectual struggle. In fact, this seems to be Peter Woit's perspective. Had he been in the interview with Ira Flatow, Flatow's conclusion might well have been that we need new mathematics, before we need new physics.

Woit points out that the mathematical formalism of quantum mechanics is not well understood. The challenge of unifying particle physics, he insists, is really the challenge of unifying the *mathematics* of the SM.[8]

In other words, the trouble with the formalism of the SM (the mathematics of compact Lie groups) is that it works very well, but we don't know why, and the trouble with string theory is

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[4] Ira Flatow, "Science Friday: String Theory," NPR, 2006
[5] David Gross, ""The Coming Revolution in Fundamental Physics"
[6] Ibid
[7] David Gross, *Einstein and the Search for Unification*
[8] Peter Woit, "The Challenge of Unifying Particle Physics"

that it doesn't work as well, and this may be because it doesn't work the way the formalism of the SM works.

But in many ways, this 20th Century, discrete, system of physics is not all that different from the 19th Century, continuous, system of physics, except that by adding the modern invention of complex numbers of size one, to the renaissance invention of real numbers, which established the original one-to-one correspondence of the set of rational and irrational numbers to the physical continuum, an additional degree of freedom is attained, which enables two, new, discrete, observables, the observables of electric charge and spin, to be added to the familiar observables of the classical system.

However, as is common knowledge now, this remarkable invention, a child of the imaginary number, which Sir Michael Atiyah calls "the biggest single invention of the human mind in history,"[9] has become "a victim of its own success," to use the words of Woit. In the final analysis, he draws the inevitable conclusion that most people likely would draw, once they have clearly understood the nature of the present perplexity: "Maybe future progress will require not just unification of physics, but unification [of physics] with mathematics..." [10]

Indeed. But, then, bringing the focus back to mathematics in this way, revives the rather out of fashion issue of mathematical formalism versus mathematical intuitionism that Atiyah emphasizes. He insists that the presence of simplicity and elegance in nature's secrets is crucial. From this perspective, he indicts string theory with one devastating observation:

> If a final theory emerges soon from string theory, we will discover a universe built on fantastically intricate mathematics.[11]

Sir Michael's unsettling point is made in the context of the "conundrum" presented to us by the invention of imaginary numbers, which he ponders with astonishment: It's perplexing, because, if, fundamentally, the origins of mathematics are to be found in nature, then the "fantastically intricate mathematics" of string theory reflects something baroque and unsatisfying in nature, which would be so surprising, given humanity's historical experience with her.[12]

On the other hand, if mathematics is just a mundane tool, a way to fashion workable formalisms, useful for studying the physical structure of the world, and thus has no fundamental, natural, origin to discover, and is nothing more than an invention of the human mind, how is it that this "biggest, single, invention of the human mind in history," the imaginary number, shows up in observed physical phenomena?[13]

Atiyah asserts that, while his position is more moderate than that of Kronecker's, author of the now famous quip, "God made the integers, all else is the work of man," he still believes that the origins of math are to be found in nature's fundamentals, which then man develops and elaborates upon. Clearly, he's convinced that the development of string theory has strayed too far into the search for a workable formalism, disconnecting it from the deeper unification of math and physics that surely awaits our understanding, in the view of mathematicians like Woit and Atiyah.

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[9] Sir Michael Atiyah, "The Nature of Space"
[10] Woit, op cit
[11] Ibid.
[12] Ibid.
[13] Ibid.

While this view is rare, it is certainly consonant with the earlier views of Sir William Rowan Hamilton, one of the founding fathers of the mathematics that makes modern science and technology possible. Early in his career, Hamilton drew the distinction between algebraic formalism (the philological approach to mathematics) and algebraic intuitionism (the theoretical approach to mathematics), lamenting the poor state of the latter, relative to the well-founded science of geometry.

In addressing this deficiency of algebra, Hamilton did not resort to basic hypotheses of mathematical theory, in terms of definitions and postulates, as mathematicians do today, but rather "he felt called upon to appeal to some physical concept for their justification."[14]

The physical concept he chose to justify his abstract notion was the observed order in the progression of time, which, to Hamilton, offered the prospect of building a new scientific algebra, which, he felt, could be built upon as firm a foundation as that of the science of geometry, which is built on the sound and natural foundation of intuition stemming from dimensional objects existing in space. He wrote:

> The argument for the conclusion that the notion of Time is connected with existing Algebra, is an induction of the following kind. The History of Algebraic Science shows that the most remarkable discoveries in it have been made, either expressly through the medium of that notion of Time, or through the closely connected (and in some sort coincident) notion of Continuous Progression. It is the genius of Algebra to consider what it reasons on as flowing, as it was the genius of Geometry to consider what it reasoned on as fixed.[15]

Certainly, the idea of considering the continuously flowing progression of time, as a natural basis for an intuitive algebra, was key, in Hamilton's mind, for removing the theoretical difficulties of negatives and imaginaries introduced by these, and other, ad hoc inventions of the human mind. He regarded his approach:

> as removing (in his opinion) the difficulties of the usual theory of Negative and Imaginary Quantities, or rather substituting a new Theory of Contrapositives and Couples, which he considers free from those old difficulties, and which is deduced from the Intuition or Original Mental Form of Time: the opposition of the (so-called) Negatives and Positives being referred by him, not to the opposition of the operations of increasing and diminishing a magnitude, but to the simpler and more extensive contrast between the relations of Before and After, or between the directions of Forward and Backward; and Pairs of Moments being used to suggest a Theory of Conjugate Functions, which gives reality and meaning to conceptions that were before Imaginary, Impossible, or Contradictory, because Mathematicians had derived them from that bounded notion of Magnitude, instead of the original and comprehensive thought of Order in Progression.[16]

However, after his discovery of quaternions, some years later, Hamilton's youthful idealism, so evident in this paper, subsided considerably, as he spent the rest of his life contemplating the mysteries of his new brainchild. Consequently, as the 19th century drew to a close, the idea of founding algebra on principles of order in progression, or as the science of pure time, had sunk into relative oblivion.

Perhaps, however, the present troubles with theoretical physics and mathematics have brought us back full circle. If the root of the problem was once that "mathematicians had derived [concepts

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[14] C.C. MacDuffee, "Algebra's Debt to Hamilton," Article in *A Collection of Papers in Memory of Sir William Rowan Hamilton*, Scripta Mathematica, 1945

[15] Sir W.R. Hamilton, "Elementary Essay on Algebra as the Science of Pure Time"

[16] Ibid

that were before imaginary, impossible, or contradictory] from that bounded notion of magnitude," then perhaps that's still the underlying problem. If so, it may be worthwhile to consider "the original and comprehensive thought of order in progression," as an alternative approach, especially since space, the foundation of the science of geometry, has been shown to be emergent, but time has not, as David Gross pointed out in the previous quote above.

Of course, the value of immediate interest, which has been derived from "the operations of increasing and diminishing a magnitude," is the Planck length, a unit of space calculated from the "bounded notion of magnitude," equal to 1.6×10^{-35} meters, where all the trouble begins. So, where did this number come from? Well, it turns out that it is the length that is dimensionally consistent with the three physical constants, c, G, and h.[17]

Derived from these constants (bounded magnitudes), the Planck length appears to be a likely candidate for the natural unit of length, as Planck first proposed. However, nobody knows if it's actually *the* natural length, or even if there is such a thing.

Clearly, it's reasonable to suspect that, in order to unify GR theory, which pairs the physical constant c and Newton's constant G, with SM theory, which pairs the constant c and Planck's constant h, setting the scale at which Heisenberg's uncertainty principle begins to apply, it would be necessary to combine all three constants together, but there is certainly nothing to demand this approach. In fact, it seems rather surprising that, given the inaccessibility and all the trouble physicists have encountered at the Planck scale, another discrete scale of space and time hasn't been suggested.

For example, another natural length can clearly be derived by combining the constant c, the one constant common to both GR and the SM, as well as almost any physical theory one can think of, with the constant R, the Rydberg constant, one of the most important and well established of all the physical constants. The natural length obtained this way, 4.558816×10^{-6} cm, as first shown by Dewey B. Larson (before updating with latest CODATA values),[18] is not only large enough to avoid problems with the Heisenberg uncertainty relation, but it also opens up a whole new avenue for investigating the structure of the physical universe. This is because, unlike the derivation of the Planck length, this new derivation of a natural length follows the "original and comprehensive thought of order in progression," introduced by Hamilton, in that it is attained using a periodic function, an ordered progression of naturally occurring space/time intervals.

In addition, this approach places the concept of natural vibration, as does string theory, in the central role of a fundamental entity, where the use of the Rydberg frequency sets up a natural unit of energy, via Planck's constant, in the equation $E = h\nu$, and a natural unit of mass, via Einstein's equation, relating energy to mass, $m = E/c^2$. In fact, this leads to the happy possibility of defining all physical units in terms of space and time only, including Newton's constant G.[19]

However, taking this approach does more than offer an escape from the prognosticated demise of space and time: It also merges the two concepts into one, as Minkowski was convinced should be done, and as Einstein has done, but this new way of merging them into one entity combines them as reciprocals, as motion, in the familiar manner, relating them in the way nature relates them.[20] In effect, this configuration redefines the flow of time, as the reciprocal of expanding space, both of which are directly observable phenomena.

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[17] Wikipedia, "Planck Units"
[18] Dewey B. Larson, *Nothing But Motion*
[19] Xavier Borg, "ST Conversion"
[20] Wikipedia, "Minkowski Space"

Typically, on first encountering this idea, our usual notion of space, as a set of fixed points, satisfying the postulates of geometry, makes the concept of space, as the reciprocal of time, a progression, seem absurd, but this is only because we are accustomed to thinking of space as a container of objects and motion as the change of the relative positions of these objects. Nevertheless, as soon as it is realized that the equation of motion, $v = \Delta s/\Delta t$, requires only changing space and changing time in its definition, and that no object is required to specify changing (i.e. increasing or decreasing) space, the idea is much more palatable.

From a mathematical standpoint, the idea that flowing time is only the reciprocal of expanding space is even more recognizable, since each dimension of space inherently has two directions, making the exponents of the binomial expansion a natural expression of the n-dimensional magnitudes of motion involved in the equations of the space/time progression. The single, temporal, dimension has no direction of progression, while the three, spatial, dimensions have two directions of progression in each dimension, or six directions in all; So combining the one temporal dimension with the three spatial dimensions, reciprocally, in the binomial expansion, has no effect on the familiar mathematical result (ignoring the binomial coefficients for the moment), as we expand the dimensions of space, from zero to three:

First dimension (0D):	$s^0/t^0 = 2^0/2^0 = 1/1$
Second dimension (1D):	$s^1/t^0 = (2^0*2^1)/2^0 = 2/1$
Third dimension (2D):	$s^2/t^0 = (2^0*2^1*2^1)/2^0 = 4/1$
Fourth dimension (3D):	$s^3/t^0 = (2^0*2^1*2^1*2^1)/2^0 = 8/1$

As shown in figure 1 below, in the fourth dimension, the so-called Euclidean three-space, the binomial coefficients of the numerator's expansion, 1331, index the orthogonality of each linear space; that is, there are three orthogonal dimensions in the 1D space and three orthogonal dimensions in the 2D space, while in the 0D and 3D spaces, there is only one dimension each, the scalar and the 3D pseudoscalar.

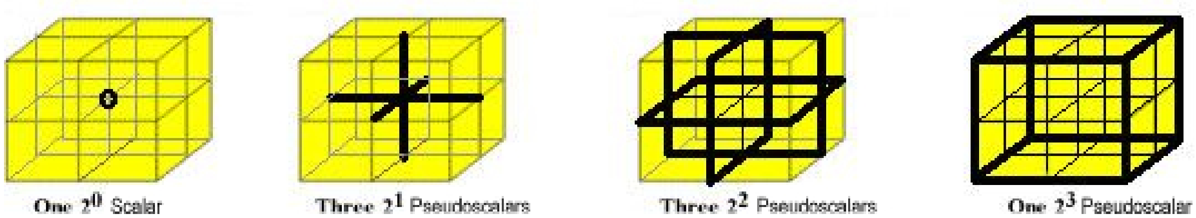

Figure 1. The Four Linear Spaces, One, Three, Three, One, of the Fourth Dimension's Structure

However, technically speaking, the 1D and 2D dimensions are the pseudoscalars of their respective linear spaces, as well, even though they are usually treated as coordinate dimensions of vector spaces. Here, they are treated as n-dimensional, pseudoscalar, space magnitudes, in their own right.

It may occur to the reader that this space/time configuration is so simple and straightforward that there must be something wrong. Why hasn't this approach been investigated long ago? The short answer is that motion has always been defined as a change in an object's location. Since pseudoscalars differ from scalars under parity transformations, because their signs change, under improper rotations, [21] if the space of the pseudoscalar is understood in terms of providing

[21] Wikipedia, "Pseudoscalar," http://en.wikipedia.org/wiki/Pseudoscalar

coordinate vector space, i.e. locations *in container space*, it introduces a major difficulty from a physics point of view, given that invariance is a core principle of physics. However, when the dimensions of a given linear space are viewed as a magnitude of n-dimensional motion, the troublesome sign change of the pseudoscalar appears in a completely different light.

The question is, though, if we eliminate the dimensions of coordinates in the vector spaces, replacing them with n-dimensional magnitudes of motion, how do we characterize the change that constitutes the motion? Without coordinates, the idea of motion, in terms of changing locations in a coordinate system goes out the window, and with them the foundations of physics. Yet, this is the heart of the matter in the trouble with theoretical physics. Quantum physics needs the fixed background of spacetime to describe the evolution of the wave equation, while general relativity introduces gravity as dynamic spacetime itself. In the words of Hawking, given that gravity is spacetime, "How can the wave function for gravity, evolve in time?"[22]

Enter string theory. "In string theory, gravity is not thought of as warped spacetime," says Hawking, but no one can find a single string theory that works in all situations. And with an almost infinite number of ways that the six, or seven, extra dimensions, which the theory requires, can be compactified, the hope that string theory will ever be of any practical use is now quite diminished.

Gross is hopeful though, because string theory only replaces zero-point particles in quantum physics, which, after all, constitutes an incremental change in the system of theory, not a revolutionary change. Yet, all indications are that a truly revolutionary change is needed. He states:

> Many of us believe…that at some point, a much more drastic revolution or discontinuity in our system of beliefs will be required. And that this revolution will likely change the way we think about space and time, maybe even eliminate them completely as a basis for our description of reality.[23]

Accordingly, many physicists have been thinking about how to do physics without recourse to the concept of time (see Carlo Rovelli's FQXI essay, "Forget time.") No doubt this would constitute a "drastic revolution or discontinuity in our system of [theory]," but it appears on the surface that this approach is only about hiding time in a complicated relativistic framework, in order to formulate quantum gravity through the back door, so-to-speak.

Approached this way, unification becomes a task of combining GR and the SM into a "mathematical superstructure," as Peter Rowlands has put it, when what is really needed is an approach that yields the structure of the physical universe in a "decent from common origin." Continuing, he writes:

> Creating a sophisticated mathematical superstructure will not provide answers to the fundamental questions that we would expect from a truly unified theory…If physics is to prove itself the most fundamental possible way of understanding the 'natural world', then it must *explain* space, time and matter, as well as use them, and it must *generate* the mathematical structures it uses; it must also show how all things that are sophisticated arise from things that are much more simple. In principle, all possible complications must be removed from the ultimate starting point. It has to be intrinsically simple and absolutely single. [24]

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[22] Stephen Hawking, "Gödel and the End of Physics"
[23] David Gross, "Viewpoints on String Theory"
[24] Peter Rowlands, *Zero to Infinity The Foundations of Physics*

That the explanation of space, time and matter must also generate the mathematical structures it uses is no doubt a profound observation, akin to the intuitionism of mathematicians like Kronecker, Atiyah and Woit. Einstein, evidently disillusioned with the explanation of space, time and matter, using the continuum mathematics of the field, long before anybody else ever was, privately pined for a true mathematical structure of the discretium, upon which to build a unified theory. He wrote to Walter Dällenbach:

> The problem seems to me [to be] how one can formulate statements about a discontinuum without calling upon a continuum (space-time) as an aid; the latter should be banned from the theory as a supplementary construction, not justified by the essence of the problem, [a construction] which corresponds to nothing "real." But we still lack the mathematical structure unfortunately. How much have I already plagued myself in this way.[25]

Clearly, the phase space of quantum mechanics, based on the ad hoc invention of complex numbers, via imaginary numbers, producing the conundrum that fills Sir Atiyah with such wonder, does just what Einstein felt should be banned from the unified theory: It calls upon the continuum (the infinite set of complex numbers of size one), as a supplementary construction, which certainly is not justified by the essence of the challenge to find a unified theory of nature, since it is a construction that does not correspond to anything real. Not only does quantum theory incorporate such a construction, but even Einstein's own concept of the fourth dimension of spacetime, as he originally conceived it, is given as $x_4 = ict$, and as such is something he insisted we should always regard as "purely imaginary." [26]

Imagine Einstein's delight, then, had he been able to find a discrete principle of fundamental physics, which was able to "*generate* the mathematical structures it uses," but, alas, it was not to be in his time. Today, though, Rowlands believes he has found such a principle in the truism that nothing is perfect. His idea is that zero, or nothing, must be the starting and ending point for constructing a unified theory, because, since it is obvious that "nothing…comes from nothing," he has to agree with Peter Atkins, a science writer he quotes as stating that "the seemingly something" of reality must be "elegantly organized nothing."[27]

While this might sound like mumbo-jumbo, it's actually consonant with most modern theories of physics, because it is now recognized that the most perfect symmetry obtainable is nothing, and since the universe is something, its current state must represent the broken symmetry of nothing. K.C. Cole explains it this way:

> …our universe could once have been so symmetrical that it amounted to nothing at all. "Nothing" is as perfect a symmetry as you can imagine, since there's nothing you can do to it that makes a difference. This nothing would have been unstable, however— like a pencil balanced perfectly (which is to say, symmetrically) on its tip. And that means— as Frank Wilczek has put it—the answer to the question "Why is there something rather than nothing?" would simply be that "nothing" is unstable.[28]

As Rowlands states it, "the universe and everything we can possible experience or conceive is also *conceptually* nothing. No other position is extreme or uncompromising enough to be able to explain *everything*."[29]

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[25] John Stachel, *Einstein From B to Z*, Birkhäuser Boston, 2001, p. 543
[26] Elliot McGucken, "Time as an Emergent Phenomenon"
[27] Rowlands, op cit
[28] K. C. Cole, "Symmetry," http://www.symmetrymagazine.org/pdfs/October-November/essay_kccole.pdf
[29] Rowlands, op cit

So, recognizing this, particle physicists are looking for evidence of Supersymmetry and the Higgs particle, while Rowlands is looking for evidence of infinite degeneracy, which are physical and mathematical manifestations of duality, the chief characteristic of symmetry, and the key to understanding how the imperfections of something can come from the perfection of nothing.

Meanwhile, taking Larson's derivation of natural units of space and time, from the observed constants of the speed of light, c, and the Rydberg constant, R, a new, non-paradoxical, means for quantizing space and time, through the folding of continuous motion by vibration, provides a perfect example of nothing becoming something, while preserving nothing in the process. To briefly explain how this can be developed requires only that we recognize that order in progression provides a basis for a new algebra, not of time alone, but of physical space/time.

For any integral number of time interval *in the progression*, the 3D pseudoscalar (spatial) expansion increases algebraically, as $(t * 2)^3$, while the scalar (temporal) expansion increases algebraically, as $t * 2^0$, but because of the inverse nature of the scalar and pseudoscalar, this configuration of 4D space/time takes the form of the function:

$$V = f(t)$$
$$= ds^3/dt^0 * t^0{}_1 - t^0{}_0 \ (d = \Delta),$$

where V is volume, s is space and t is time. Therefore, the space/time progression, in the four linear spaces (2^0, 2^1, 2^2, 2^3) of the algebra, generates the series of natural counting numbers, times the nD aspect of the 4D basis in each dimension, $1*2^0$, $3*2^1$, $3*2^2$, $1*2^3$, yielding a formula for the progression in each linear space, $n(2^0)$, $3n(2^1)$, $3n^2(2^2)$, $n^3(2^3)$, for a given $t = t^0{}_n - t^0{}_0$.

Since the Bott periodicity theorem[30] proves that there are no new phenomena beyond the Euclidean three-space, these four, n-dimensional, series of geometric magnitudes, (again, as order in progression), are what we have to work with, but interestingly enough, the 10 dimensions of superstring theory (and 11 dimensions of M theory) must play in these same four linear spaces of the fourth dimension, as well; and, clearly, the continuum of Einstein's spacetime, with the fourth dimension, x_4 = ict (indispensable to GR), as an imaginary magnitude identified with time, and, at time t = 1, the rotational continuum of complex numbers of size one, the unit circle in the complex plane (indispensable to SM), are found here too.

For uniform motion, the space/time progression, using Larson's natural units, is equal to c; that is, the 3 pseudoscalars expand at unit velocity, $v = ds^3/dt^0 = 1/1$. Thus, measuring the expansion from any point, n, in the progression, to the point n + 1, produces the unit pseudoscalars, a cross section of which is depicted in figure 2 below:

[30] Wikipedia, "Bott Periodicity Theorem"

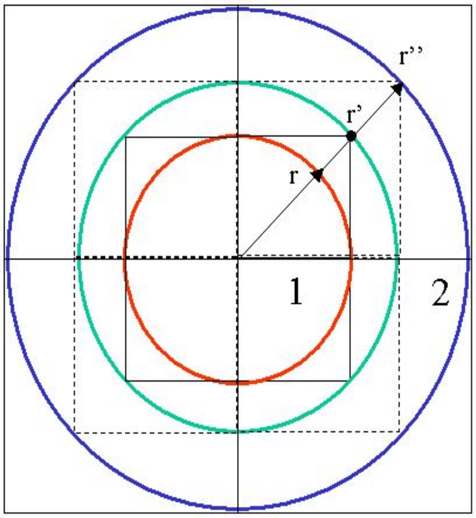

Figure 2. The Cross Section of the Unit Pseudoscalar, with the Real Unit Circle (red), the Complex Unit Circle (green), and the Inverse Real Unit Circle (blue) Superimposed Upon It

There is much to say about this figure, but most of it will have to wait for a subsequent essay. Suffice it to say now that the expansion of the pseudoscalars, at unit speed, constitutes a physical and mathematical starting point of infinite degeneracy, for a physical system consisting of nothing but space/time; that is, n/n = 1/1 = 0, in terms of motion, because unit motion, or a space/time ratio of 1/1, is perfectly symmetrical, or balanced, and only nothing is perfectly symmetrical, as Cole and Rowlands explained.

However, introducing a unit vibration, wherein a parity transformation of the pseudoscalars occurs at the end of each temporal unit, or vice versa, breaks the symmetry of the 1/1 space/time ratio, and produces a unit temporal, or a unit spatial, speed displacement, a unit speed-displacement from unit speed, we might say. In this way, three, and only three, space/time ratios emerge: 1/2, 1/1, 2/1, equivalent to three integers, -1, 0, 1, algebraically, corresponding to the n-dimensional properties of the three circles (spheres) of figure 2 above, geometrically speaking (i.e. in terms of π).

Since the unit integers are the foundation of all mathematics and physics, and given that they are generated by the simple physical processes of space/time, as order in progression, the consequences that follow portend an exciting new system of physical theory.