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Why natural science needs phenomenological philosophy

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ABSTRACT

Through an exploration of theoretical physics, this paper suggests the need for regrounding natural science in phenomenological philosophy. To begin, the philosophical roots of the prevailing scientific paradigm are traced to the thinking of Plato, Descartes, and Newton. The crisis in modern science is then investigated, tracking developments in physics, science's premier discipline. Einsteinian special relativity is interpreted as a response to the threat of discontinuity implied by the Michelson-Morley experiment, a challenge to classical objectivism that Einstein sought to counteract. We see that Einstein's efforts to banish discontinuity ultimately fall into the "black hole" predicted in his general theory of relativity. The unavoidable discontinuity that haunts Einstein's theory is also central to quantum mechanics. Here too the attempt has been made to manage discontinuity, only to have this strategy thwarted in the end by the intractable problem of quantum gravity. The irrepressible discontinuity manifested in the phenomena of modern physics proves to be linked to a merging of subject and object that flies in the face of Cartesian philosophy. To accommodate these radically non-classical phenomena, a new philosophical foundation is called for: *phenomenology*. Phenomenological philosophy is elaborated through Merleau-Ponty's concept of *depth* and is then brought into focus for use in theoretical physics via qualitative work with topology and hypercomplex numbers. In the final part of this paper, a detailed summary is offered of the specific application of topological phenomenology to quantum gravity that was systematically articulated in *The Self-Evolving Cosmos* (Rosen, 2008a).

1. Classical science in crisis

The unquestioned point of departure for Newtonian science is its self-evident intuition of *object-in-space-before-subject* (Rosen, 2004, 2008a). This formulation derives from Plato, who stated in the *Timaeus* that "we must make a threefold distinction and think of that which becomes, that in which it becomes, and the model which it resembles" (1965, 69). "That which becomes" corresponds to the *object* term in the formula; this ontological category comprises the things and events that we observe and measure. The context in which we make these observations is what Plato called the "receptacle," a concept that evolved into our modern idea of *space*. And the "model" that the transitory object "resembles" is the "eternal object," the changeless form or archetype. For Plato, this perfect form is *eidos*, a rational idea or ordering principle in the mind of the Demiurge. Using his archetypal thoughts as his blueprints and the receptacle as his container, this Divine Creator fashions an orderly world of particular objects and events. The Cartesian descendent of the Platonic Demiurge constitutes the third term of science's axiomatic formula: the *subject*, idealized in classical mechanics as a "Laplacean demon," a global observer that is detached from the concrete world but that has "an instantaneous bird's eye view of everything" (Matsuno and Salthe, 1995, 311). To summarize the underlying trichotomy of classical metaphysics implicit in the work Descartes, Newton, and their successors: the object is *what* is observed, space is the continuous medium *through* which the observation occurs, and the subject is the transcendent perspective *from* which the observation is made. These three terms are taken to be categorically separate from each other.

Despite science's long-held ideal of detached, purely objective observation, in actual practice the observing subject has always interacted with the observations made. Though this "human factor" in science had never been wholly deniable, up to the middle of the nineteenth century it was possible for the subjective element to be minimized and marginalized, attributed to errors in measurement that were readily manageable and thus had little impact on the primary aim of apodictic certainty. But the Newtonian ideal was seriously challenged toward the end of the nineteenth century.

Philosopher Karl Jaspers commented on how science changed in the century that followed the death of Kant in 1804: "It extends

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further than in Kant's time; it is more radical than ever, both in the precision of its methods and in its consequences" (1941/1975, 166). But Jaspers goes on to tell us that, in the very extension and refinement of science, the *limitations* of scientific knowing have become much more transparent: "We experience the limits of science as the limits of our ability to know and as limits of our realization of the world through knowledge … the knowledge of science fails in the face of all ultimate questions" (1941/1975, 167). For my part, I would emphasize that the barrier science reached as it progressed into the nineteenth century was not merely an external one. It was not simply that the scientific approach was found to be inapplicable to traditionally nonscientific fields of knowledge. It was that fundamental problems arose within science itself. As physics pressed toward ever higher levels of exactitude, extending itself to the extremes of measurement, to the limits of its scales—ultra-high velocities, sub-microscopic distances, and so on—some of its most basic expectations were upset.

The initial upheaval came with the Michelson-Morley experiment on light (1887). This research raised doubts about the luminiferous ether that Maxwell had imagined to be the medium for propagating electromagnetic energy. Just as relatively crude mechanical phenomena like water waves and sound waves could be taken as transmitted through Newtonian space via the media of water and air (respectively), Maxwell supposed that the subtler electromagnetic energy he was investigating was transmitted through the ether, a highly refined medium thought to pervade the whole universe. Possessing few properties and no action of its own, the ether was presumed to serve exclusively as the framework within which the continuous motions of coarser substances could be measured and analyzed—including the motion of light. Maxwell's ether hypothesis reflected the underlying idea that light could be viewed as a mechanical force that passed through the Newtonian continuum like any other force—in other words, that light could be treated as an object in space that could be observed objectively by a Newtonian subject detached from that space. In so postulating the existence of a luminiferous ether, the old formula of object-in-space-before-subject was tacitly maintained. But the postulate proved untenable.

If it were true that light moved through a motionless ethereal continuum, then a key principle of classical mechanics should apply: the addition of velocities. Assuming light to propagate through the ether at the absolute speed of c (~186,000 mps), a traveler moving toward a beam of light should observe the beam to be approaching her at a velocity greater than c, her own velocity being added to c to obtain the higher relative velocity. Similarly, if the light beam and the observer are moving away from each other through the ether, the relative velocity of the light beam would be less than c, the observer's velocity now being subtracted from c. What Michelson and Morley discovered was that the velocity of light actually always appeared to be the same, regardless of its direction of motion relative to the observer. This astonishing result sounded the death knell of the ether theory.

The result of the Michelson-Morley experiment was indeed baffling to the classical "eye." Is it not an obvious fact of perception that, if I change my perspective on an object I am viewing, its appearance will change accordingly? What the experiment demonstrated in its abstract way was that, when the "object" being considered is *light*, the familiar principle of perspective does not apply. It would certainly look strange to me if I got up from this computer screen I am sitting at, moved all the way to the right of it so that I was viewing the screen at an acute angle, but found that the screen had the same full, square appearance as when I was sitting directly in front of it! Analogously, this is what Michelson and Morley "saw" when they looked at light from different "angles" (reference frames). This strange outcome made it clear that the phenomenon of light does not behave the way mechanical phenomena do, thus suggesting that electromagnetic phenomena are not strictly governed by the classical laws of Newtonian space.

But just why was it that the velocity of light did not change regardless of the frame of reference that Michelson and Morley adopted? Why did light "look" the same to them no matter what perspective upon it they assumed? I propose it was because, in confronting the phenomenon of light, they were not encountering an object to be seen, but that *by which* they saw. As the physicist Mendel Sachs put it in his inquiry into the meaning of light: "What is 'it' that propagates from an emitter of light, such as the sun, to an absorber of light, such as one's eye? Is 'it' truly a thing on its own, or is it a manifestation of the coupling of an emitter to an absorber?" (1999, 14). Sachs's rhetorical question intimates that light—instead of lending itself to being treated as an object open to the scrutiny of a subject that stands apart from it—must be understood as entailing the *inseparable blending of subject and object* (Rosen, 2004, 20; 2008a, 164). This computer screen surely does not look the same to me from every perspective, but would not my *viewing* of the screen look the same? In attempting to observe the light by which the screen is perceived, it seems I would be confronted with the prospect of "viewing my own viewing," and this would mean that I would not encounter the concrete variations in appearance that attend the observation of an object from a viewpoint that itself is not viewed. At bottom then, the finding of Michelson and Morley evidently called into question the classical intuition of object-in-space-before-subject that had implicitly governed the work of science for many centuries.

Let me be clear that the classical formula is hyphenated to indicate that its three main terms are mutually interdependent. So, if there is no separation of subject and object in the phenomenon of light, there can be no *space*, since the existence of space presupposes that separation. Space is therefore no free-standing abstraction. Instead of simply existing on its own, it exists as a container of concrete objects, and these objects necessarily are contained in such a way that they are categorically divided from the subject, he who is *un*contained (cf. Descartes' sharp distinction between *res extensa*, an object extended in space, and *res cogitans*, a mental substance or thinking subject not contained in space). If the objects were not thus sealed into space, if the subject was not sealed out, the spatial seal would be broken. Just such a breach is signified by the fusion of subject and object encountered in the phenomenon of light. It was for this reason that the findings of Michelson and Morley, instead of confirming the existence of the "ethereal continuum" as expected, pointed to an alarming loss of continuity.

2. Relativity: from one "black hole" to another

The crisis precipitated by the Michelson-Morley experiment was seemingly addressed by the Einsteinian revolution in physics. But to what extent was Einstein's theory truly revolutionary?

The theory of relativity is essentially co-optative (Rosen, 2004, 22). It accommodates the electromagnetic challenge to classical intuition in such a way that the challenge loses its force. The brilliance of Einstein lay in the fact that, at the very same time that he accepted the rupture of the classical continuum (he could hardly do otherwise, given the demise of the ether), he found a way to seamlessly repair it. It is this that is responsible for the popular confusion over the meaning of the term "relative" in Einstein's theory.

Space and time are indeed relativized in Einstein's theory. Prior to Einstein, these dimensions were assumed to be absolute parameters of change that did not themselves change. The space and time of Newton and Descartes were taken as perfectly homogeneous continua. What did change on the classical view, what was subject to discontinuity, were not space and time per se but the concrete objects contained therein. How did Einstein respond when the Michelson-Morley experiment cast doubt on the older assumptions about space and time? In effect, he said: Let space and time themselves change (in the theory, time dilates and space contracts at high relative velocities). This transformation of space and time certainly appears to dynamize physics and render it concrete, for now, not only do objective events entail dynamic processes; also in process is what previously had been taken as the abstract, utterly static framework for those events. In thus introducing change at the fundamental level of space and time themselves, Einstein did seem to be challenging the classical order of object-in-space(-and-time)-before-subject. And yet, the philosopher Bertrand Russell (1925) was prompted to declare that Einstein's theory was *misnamed*, since the theory actually seeks a description of nature that is anything but relative!

It is clearly an oversimplification of Einsteinian relativity to say, without qualification, that, in it, space and time change. Einstein did not simply posit the variability of space and time. Instead he declared that, while these terms previously had been taken as invariant, they must now be seen as undergoing change *within a new context of invariance*. Yes, time is now deemed relative. No longer can we overcome the "human factor" by assuming a universal clock that enables local observers in different frames of reference, traveling at different velocities, to synchronize their watches with absolute precision. But while *time* is no longer absolute, *space-time is*. All concrete observational perspectives, involving variations in velocity, are rendered strictly equivalent in relation to the four-dimensional space-time continuum whose unity is conferred by *c*, the constant velocity of light. The Michelson-Morley experiment had intimated the possibility that light's constancy was indicative of a blending of subject and object that confounded classical intuition. Einstein foreclosed this interpretive option before it could even reach the threshold of conscious consideration. For Einstein, light is hardly a merging of subject and object but is simply an abstract object: it is the empirical constant necessary for the objective determination of space-time events. Thus, most essentially, Einsteinian "relativity" was actually not about relativizing or dynamizing nature; it did not embody a genuine recognition that there is fundamental change or discontinuity in the world, that the world is in process. Einstein's success, his profound influence on twentieth century physics, was rooted in his ability to accommodate the nineteenth century challenge to classical physics in such a way that the classical viewpoint is basically upheld. The old order of space and time is supplanted by Einstein, yet, with scarcely a pause, it is replaced by an even more abstract order of this kind: that of the four-dimensional space-time continuum. Here there is still the object, or rather, the objectified relativistic event; still the static continuum that contains the event, divesting it of its vitality; and still the detached, idealized subject who analyzes all this from afar. To be sure, Einstein significantly updated the details of the classical formula, but he did this in order to maintain the viability of its basic terms.

To all appearances, Einstein's theory of relativity was a resounding success. However, when he unveiled this idea in 1905, he was well aware that it was incomplete. Einstein came to call his initial theory "special relativity" because it was limited to the ideal case of coordinate systems that moved uniformly. In the real world, however, systems typically *change* their state of motion, speed up or slow down. With the special theory published, Einstein turned to the task of accounting for the relative motion of *all* reference frames, whether or not the motion was uniform. This effort eventuated in the 1915 publication of the general theory of relativity. By switching from the Minkowski flat space of special relativity to the far more general Riemannian manifold, Einstein could now explain the interaction of systems in non-uniform relative motion. The flexibility of Riemannian geometry permitted Einstein to gauge the degree of non-uniformity of motion in precise terms by associating it with the degree of curvature in the manifold. Space-time is without curvature for systems in uniform motion and becomes progressively more curved as the acceleration of the reference frame increases. Applying the principle of general relativity that establishes the equivalence of inertial and gravitational masses, space-time curvature is related to gravitational effects: the greater the gravitational mass of a body, the more curved is the space-time continuum.

Now, while Einstein found it necessary to adopt this approach, he soon realized that it had its limitations. For, there were solutions to the field equations of general relativity that predicted *infinite* curvature. That is, if a gravitational body were massive enough, the curvature of space-time would become so great that a singularity would be produced in the continuum. What this meant is that analytic continuity would be lost and the theory would fail! However, for that to happen, the mass density of the gravitational body indeed would have to be enormous. When the general theory was first propounded in 1915, the existence of such astrophysical bodies was taken as purely hypothetical. But, as the twentieth century wore on, the possibility of stellar objects whose masses were sufficient to produce "black holes" in space began to be considered more seriously. This led physicist Brandon Carter (1968) to raise explicit doubts about Einstein's theory: Would it be able to survive its prediction of gravitational collapse? By the end of the twentieth century, empirical evidence for black holes had only grown stronger, and, now, in the new millennium, the evidence seems almost irrefutable. One might think that, as a consequence, Einstein's theory might have lost significant influence. Before considering why that is not the case, let me summarize the theory's course of development and reflect on its meaning.

Einsteinian relativity evolved out of the attempt to circumvent the "black hole" that was created when Michelson and Morley could not confirm the existence of the luminiferous ethereal continuum. The effect of Einstein's theory was to plug the implicit gap in three-dimensional space by postulating a four-dimensional space-time continuum. To generalize the new account to non-uniform motion, Einstein posited the curvature of space-time. What we are seeing, in effect, is that the four-dimensional approach used to compensate for the absence of continuity in three-dimensional space winds up re-introducing *dis*continuity. Even though general relativity permits one to establish invariances involving non-uniform motion, invariances that presuppose continuity, the *greater* the non-uniformity, the greater is the curvature of space-time, and the closer one then approaches to the point where invariance breaks down and continuity is lost. So it seems that the moment curved Riemannian geometry was applied to generalize Einstein's remedy for discontinuity, a new order of discontinuity was presaged. In the end then, Einsteinian relativity does not effectively address the underlying crisis in theoretical physics precipitated by the Michelson-Morley experiment. Why has the inherent discontinuity of Einstein's theory not undermined its influence more completely? Perhaps it is because the other preeminent field of modern physics has created an atmosphere in which discontinuity can better be tolerated and its ultimate consequences better denied.

3. Quantum mechanics, quantum gravity, and the need for a new foundation

At the close of the nineteenth century, just around the time when physicists were digesting the Michelson-Morley findings, another groundbreaking investigation of electromagnetism was being conducted. To recapitulate this famous experiment, Max Planck was studying blackbody radiation, the emission of electromagnetic energy in a completely absorbent medium (a closed cavity that does not reflect light but soaks it up, discharging the energy internally). Classical theory faced a difficulty here that was on a par with the problem engendered by the Michelson-Morley experiment. If the traditional analysis was correct, energy should be transmitted in a smoothly continuous fashion. Yet this assumption leads to the peculiar prediction that, if a non-reflective body is exposed to intense heat, it should radiate an *infinite amount* of energy—a result that clearly is not borne out by empirical observation. Planck responded to the contradiction by boldly amending the underlying classical assumption. He proposed that light, rather than radiating in a continuous manner, is transmitted in discrete bundles, *quanta*. The introduction of discontinuity into the theory now brought a remarkable correspondence with empirical data. The new quantum theory could predict laboratory findings to a high degree of accuracy by adding just one parameter, h. This is the constant of proportionality that relates the energy (E) of a quantum of radiation to the frequency (v) of the oscillation that produced it: $E = hv$. The numerical value of h is 6.63×10^{-34} J s. The extremely small value of Planck's constant is consistent with the fact that, in the familiar world of large-scale happenings, energy does appear to propagate in a smoothly continuous fashion. It is only when we "look more closely," examining the microscopic properties of light, that we notice its discontinuous, quantized grain.

It took a generation for the truly revolutionary implications of quantum mechanics to become clear. Under the lingering sway of classical thinking, it was natural to assume that the discontinuity of energy found in QM was not really fundamental. For, if the properties of a quantum of energy were to be subject to complete scientific determination, it seemed as if the discontinuity ultimately had to be reducible to continuous expression via an underlying space-time substrate. Yet, by 1930, most physicists had arrived at the conclusion that no such reduction is possible. At this point, the majority of researchers felt obliged to accept the idea that Planck's microscopic quantization implies a basic indivisibility of energy that confounds analytic continuity (which assumes infinite divisibility; see Rosen, 2004). With the continuity principle thus subverted, all classical thinking about space and time, including that of Einstein, was called into question. It was this implication that led philosopher Milič Čapek to comment that, in light of quantum mechanics, "the concepts of spatial and temporal continuity are hardly adequate tools for dealing with the microphysical reality" (1961, 238).

The microscopic loss of continuity may be better understood by considering more closely Planck's constant, h. This number gives a quantum of *action*. If we rewrite Planck's basic equation, $E = hv$, by replacing frequency (v) with its inverse, namely, time, we then have $E = h/T$ or $h = ET$, and in physics, energy multiplied by time is a measure of action. The *angularity* of quantized action, its internal "spin," is expressed by the application of phase, as given in the formula $h/2\Pi = \hbar$. Here h is operated upon by a phase of 2Π radians, equivalent to a turn of 360°. In quantum mechanics, $\hbar$ is regarded as an indivisible "atom of process," one not reducible to smaller units that could be applied in its quantitative analysis. Thus, at the sub-microscopic Planck threshold of 10^{-35} m, the analytical continuity of space gives way to a "graininess" or discreteness that admits of no further quantitative determination. We see here the intimate relationship between the indivisibility of the quantum domain and its basic indeterminacy or uncertainty. According to Heisenberg's uncertainty principle, there is a built-in limit to the information we can obtain about the physical properties of quantum systems. This limitation can be stated in terms of Planck's constant: $\Delta p \Delta q \approx \hbar$, where p and q are variables such as position and momentum, or time and energy (variables that are paired or conjugated so as to be essentially indivisible from *each other*). The formula says that the product of the uncertainties (Δs) of such paired terms approximately equals (cannot be less than) the value of Planck's constant. Clearly then, the phasic indivisibility ($h/2\Pi$) of Planck-level action is equivalent to its uncertainty ($\Delta p \Delta q$).

There is another way to look at the quantum uncertainty. Nearing the sub-microscopic Planck length, it appears that precise objective measurement is thwarted by the fact that the energy that must be transferred to a system in order to observe it *disturbs* that system significantly. This well-known "problem of measurement" in quantum mechanics expresses quantum indivisibility in terms of the indivisibility of the *observer and the observed*. It seems that in QM, the observer no longer can maintain the classical posture of detached objectivity; unavoidably, s/he will be an active participant. Evidently this means that quantum mechanical action cannot be regarded merely as objective but must be seen as entailing an intimate merging of object and subject that defies Newtonian order. Therefore, just as the old formula of object-in-space-before-subject was thrown into doubt by the Michelson-Morley experiment on the velocity of light, so too was it challenged by Planck's blackbody research. Could we say that, whereas Einstein attempted to plug the hole in the spatial vessel by denying it (via his proposal of a four-dimensional space-time continuum), Planck and his successors fully *accepted* the discontinuity? Did quantum physics give up Einstein's effort to uphold objectivism? Did it embrace the indivisibility of object and subject? These questions must be answered in the negative. QM certainly did not just relinquish continuity and the objectivity it conferred. Instead, the implicit attempt was made to retain continuity through an approach that is even more abstract than Einstein's.

Let us consider a central feature of the quantum theoretic formalism: analysis by probability. According to the classical ideal, the extensive continuum is infinitely differentiable, which means that the position of a system within it is always uniquely determinable. When QM was confronted with the *inability* to precisely determine the position of a particle in microspace, it did not merely resign itself to the lack of continuity that creates this fundamental uncertainty. Instead of allowing the conclusion that a microsystem in principle cannot occupy a completely distinct position—which would be tantamount to admitting that microspace is not completely continuous—a multiplicity of continuous spaces was axiomatically invoked to account for the "probable" positions of the particle: "it" is locally "here" with a certain probability, or "there" with another. This collection of spaces is known as *Hilbert space*. *N*-dimensional Hilbert space plays a role not unlike that played by Einstein's four-dimensional space-time continuum: it responds to the threat of discontinuity by restoring continuity through an act of abstraction. And, as with Einsteinian relativity, the quantum mechanical abstraction of classical space brings with it an abstraction of subjectivity.

There is a substantial difference between the pre-Einsteinian and Einsteinian versions of the classical posture. In the former, we have objective events occurring in three-dimensional space before the observing gaze of an idealized global subject (a "Laplacean demon"). In the latter—where the local space and time of the concrete observer could not merely be discounted, subjectivity itself is taken as object, with the "object" now being regarded as an *observational* event transpiring in four-dimensional space-time. Whereas three-dimensional events are concretely observable, the fourth dimension of Einsteinian relativity is an abstraction. The higher-order Einsteinian observer of these four-dimensional acts of observation functions as a kind of "hyper-Laplacean demon," for this omniscient being is a further step removed from concrete reality than was his Newtonian predecessor. Nevertheless, in both cases, the traditional stance is strictly maintained. In both, we have object-in-space-before-subject.

Like Einsteinian relativity, quantum mechanics implicitly transforms the old subject into an object cast before a more abstract, higher-order subject. In effect, the quantum mechanical analyst assumes a superordinate vantage point from which s/he is able to consider alternative acts of classical observation and weight them probabilistically, with each act corresponding to a different subspace of the Hilbert space. Similar to relativistic analysis, the "objects" to be analyzed are not mere concrete substances but observations themselves—what Max Planck called the "run of our perceptions" (Planck quoted in Jahn and Dunne, 1984, 9). If the "scientific objectivity" of QM's analysis of observation is to be maintained, the implicit observational activity of the *analyst* of observation must itself be *exempted* from the analysis. That is to say, two ontologically distinct levels of observational or subjective activity have to exist: that which is to be analyzed, and that through which the analysis is to take place. The former is constituted by the old subjective activity that is now objectified within the framework of the Hilbert space, whereas the latter corresponds to the more abstract, higher-order, wholly implicit activity of the quantum mechanical subject standing outside of Hilbert space. It is clear that this QM subject assumes the same detached, "purely objective" stance as did his Newtonian forerunner. Still operative in its essential relations is the basic formula of object-in-space-before-subject.

Nevertheless, Hilbert space does not retain its usefulness for all levels of energy at all scales of magnification. Its range of applicability is limited to the comparatively low-energy regime that lies above the Planck length of 10^{-35} m. It is true that, in studying the phenomenon of electromagnetic radiation, Planck brought us into an energy domain in which classical continuity was shaken, and, along with it, the certitude of classical objectivism. But while the domain in question is surely microscopic and Planckian uncertainty becomes a significant factor here (whereas, in the large-scale classical world, it does not), this realm of interaction remains considerably above the *ultra*-microscopic, ultra-energetic Planck scale where discontinuity becomes completely unmanageable.

However, in the course of the twentieth century, physicists probed the microworld ever more deeply as they sought to advance their project of arriving at a unified understanding of nature. Whereas the fundamental forces of nature appear irreconcilable at lower energy levels and orders of magnification, physicists, by pushing their quantum mechanical research into the high-energy, sub-microscopic domain, could now account for the atomic decay force (the weak interaction) and the electromagnetic force in a unified manner. Going still further into the microworld, impressive progress was made on a "grand unification" that incorporated the strong nuclear force. And yet, in drawing closer and closer to the Planck length, the element of uncertainty only grew greater.

To complete its quest for unity, physics now faces one final task. It must include in its quantum mechanical analysis the one force of nature hitherto unaccounted for, namely, gravitation. The problem is that gravity, unlike the non-gravitational forces, resists QM treatment until the bitter end. That is, gravitational energy behaves classically, appears to retain its continuity all the way down the scale of magnitude to the Planck length itself. It is precisely here that a QM theory of gravitation would have to operate to fulfill its aim of total unification. Of course, the Planck length is the threshold at which spatiotemporal turbulence goes out of control and uncertainty becomes all consuming. Crossing this threshold, the quasi-continuity of Hilbert space yields to utter discontinuity. Not even a probabilistic analysis of nature is possible here, as is reflected in the unworkable probability values obtained for equations dealing with sub-Planckian reality.

It is interesting to note how quantum mechanics and Einstein's theory of gravitation converge in negation. It is not merely that the former reaches its Planckian limit and encounters irrepressible discontinuity in a manner that is *analogous* to the black-hole limitation confronting the latter. For what may seem at first like analogous but different limitations, actually can be said to constitute the very same limitation.

The work of physicist Arthur Eddington (1946) contributed to an understanding of this. In his own effort at unification, we find the implication that quantum mechanical discontinuity (and its associated uncertainty) is equivalent to relativistic curvature. Speaking of the fundamental relation "between the microscopic constant σ and the cosmological constants R_0, N," Eddington declared that "curvature and [quantum mechanical] wave functions are alternative ways of representing distributions of energy and momentum" (1946, 46). Eddington's findings are consistent with the fact mentioned earlier that, the greater the curvature of space-time, the closer we approach to the loss of continuity realized in the singularity of the black hole. Therefore, the production of curvature in general relativity, which culminates in the infinite warping of space-time found in the heart of a black hole, maps onto the production of Planckian discontinuity, the degree of which progressively increases as we descend into the microcosmos. It seems then that the black hole singularity of general relativity is none other than the manifestation of quantized gravitational energy at the Planck length. But aren't black holes *large-scale* phenomena, astrophysical events taking place at the opposite end of the scale of magnitude from the microphysical happenings of quantum mechanics? On the contrary, upon entering the singularity of the black hole, the pervasive uncertainty about distance that arises here (owing to the loss of continuity) renders any notion of "large-scale" vs. "small-scale" inoperative. Simply stated, the scale of magnitude collapses.

What we are seeing is that Einstein's "macroscopic" theory comes to an end at the very same place where quantum mechanics ends: at the "microscopic" Planckian limit. Here, in this singularity, relativity theory and quantum mechanics coalesce. Of course, this "unification of the field" is hardly what science had intended, since the unity is realized in negation, marking as it does the failure of determinative analysis.

It was in the 1970s, following the progress achieved with grand unification, that work on a theory of quantum gravity began in earnest. And this is when confrontation with the chaos of the Planck realm could no longer be avoided. The equations that would unify all four forces of nature were now completely unable to contain the wildly fluctuating Planckian energies, as manifested by the infinite probabilities that turned up to render those equations useless. Consequently, progress was now blocked and has continued to be thwarted up to the present time. Over the past forty years, there has been little meaningful movement toward an effective theory of quantum gravity. Musing ironically on this, physicist Lee Smolin (2006) observed that, "for more than two centuries … our understanding of the laws of nature expanded rapidly … . [yet] today, despite our best efforts, what we know for certain about these laws is no more than what we knew back in the 1970s" (viii).

What "best efforts" is Smolin referring to? Since the 1970s, the quest for a mathematical unification of nature has largely been dominated by an approach known as *string theory*. In this endeavor, the attempt is made to avoid probing below the Planck threshold simply by assuming that the smallest constituents of nature are not indefinitely miniscule point-particles as previous theory had assumed, but string-like vibrating elements of finite extension conveniently scaled at the Planck length. It is because this stratagem has managed to eliminate infinite terms from quantum gravitational equations that it has become the preferred approach. But the price paid for this positivistic ploy has come to be acknowledged (Smolin, 2006; Woit, 2006). In my own explorations of the matter (Rosen, 2004, 2008a, 2008b, 2013), I have identified several problems with string theory.

First, while it is true that string theory serves the classical ontology by sidestepping sub-Planckian ambiguity, an *epistemic* ambiguity takes its place. String theory's general equations may be free of unmanageable infinities, but theorists must be able to solve these highly abstract equations in a manner that produces a specific description of the world as we know it. As things now stand, the equations yield a vast array of possible solutions with no guiding principle by means of which the field can be narrowed in unique correspondence with known physical reality. A second limitation of the theory is the evident impossibility of objectively testing it in a direct fashion since, according to physicist Brian Greene, the test would have to be conducted on a scale "some hundred million billion times smaller than anything we can directly probe experimentally [!]" (1999, 212). Finally, the theory seems to contradict itself in its assumption of fundamental particles with finite extension. "Strings are truly fundamental," says Greene, "they are 'atoms', uncuttable constituents" of nature. So, "even though strings have spatial extent, the question of their composition is without any content" (141). But isn't this a contradiction? For—at least according to the classical concept of the continuum not explicitly challenged by string theory, to be spatially extended is to be *cuttable*, in fact, infinitely divisible. How then could a string be a fundamental particle, an atomic or indivisible ingredient of nature, when it is spatially extended? In sum, string theory is ambiguous, objectively untestable, and it contradicts itself when seen in classical terms.

In his book *The Trouble With Physics*, Smolin (2006) winds up calling for a different style of doing physics than what has been practiced since the advent of string theory. He advocates a "more reflective, risky, and philosophical style" (294) that confronts "the deep philosophical and foundational issues in physics" (290). I applaud this call for a more philosophically-oriented physics, and I propose that the recent stalemate in physics suggests it will no longer be possible for us to rely on the *old* philosophical foundation. With the coming to prominence of the quantum gravity issue, theoretical physics evidently has reached an unprecedented watershed. The problems confronted by string theory, and by quantum gravity in general, are not merely theoretical ones that can be resolved within the extant philosophical framework of object-in-space-before-subject. Rather, the difficulty lies squarely with that framework itself. The trans-Planckian dissolution of spatiotemporal continuity and fusion of subject and object strike at the very heart of the ancient formula. I therefore venture to say that any new theory presupposing said formula will fail to bring the unification that is sought. But if the long-dominant tradition of philosophy is not equal to the task of effectively grounding a unified physics, is there any alternative philosophical foundation that can serve in this capacity? I believe there is.

4. A brief introduction to phenomenological philosophy

What I am proposing is that meeting the challenge of quantum gravity requires that physics be regrounded not merely in a new theory, but in a new philosophy, one that can accommodate the intimate interplay of subject and object. Beginning in the twentieth century, the classical tradition has been perceptively questioned by the proponents of a philosophical initiative known as *phenomenology*. After describing the general features of this approach in the present section, in the next section I will focus on a phenomenological concept that has immediate relevance for the current impasse in theoretical physics.

The phenomenological movement is rooted in the nineteenth century existentialist writings of thinkers like Kierkegaard, Nietzsche, and Dostoevsky. It takes its contemporary form through the work of its principal figures: Edmund Husserl, Martin Heidegger, and Maurice Merleau-Ponty. In terms of the present paper, phenomenology can be seen most essentially as a critique of the classical trichotomy of object-in-space-before-subject. To the phenomenologist, the activities of the detached Cartesian subject are idealizing objectifications of the world that conceal the concrete reality of the *lifeworld* (Husserl, 1936/1970). Obscured by the lofty abstractions of European science, this earthy realm of lived experience is inhabited by subjects that are not anonymous, that do not fly above the world, exerting their influence from afar. In the lifeworld, the subject is a fully situated, fully-fledged participant engaging in transactions so intimately entangling that it can no longer rightly be taken as separated either from its objects, or from the worldly context itself. As Heidegger put it, the down-to-earth, living subject is a *being-in-the-world* (1927/1962), a being involved in

> a much richer relation than merely the spatial one of being located in the world .... This wider kind of personal or existential "inhood" implies the whole relation of "dwelling" in a place. We are not simply located there, but are bound to it by all the ties of work, interest, affection, and so on. (Macquarrie, 1968, 14–15)

It is clear that all three terms of the classical formulation are affected by the phenomenological move. To reiterate the traditional account, the object is *what* is experienced, the subject is the transcendent perspective *from* which the experience is had, and space is the continuous medium *through* which the experience occurs. In this approach, objects are taken as simply external to each other and as appearing within a spatial continuum of *sheer* externality—space's infinite divisibility, or, in Heidegger's words, the "'outside-of-one-another' of the multiplicity of points" (1927/1962, 481). The agents operating upon the objects constitute a third kind of externality, acting as they do from a transcendent vantage point beyond the objects in space. It is this privileging of external relations that is counteracted in the phenomenological approach. Notwithstanding the Platonic/Cartesian idealization of the world, in the underlying *lifeworld* there is no object with boundaries so sharply defined that it is closed off completely from other objects. The lifeworld is characterized instead by the *transpermeation* of objects (the quantum scientist might say "superposition"), by their mutual interpenetration, by the "reciprocal insertion and intertwining of one in the other," as Merleau-Ponty put it (1968, 138). With objects thus related by way of mutual containment, no *separate* container is required to mediate their relations, as would have to be the case with externally related objects. Objects are therefore no longer to be thought of as contained in space like things in a box, for, in containing each other, they contain themselves. At the same time, it must also be understood that, in the lifeworld, there can be no peremptory division of object and subject. The lifeworld subject, far from being the disengaged, high-flying *deus ex machina* of Descartes, finds itself down among the objects, is "one of the visibles" (Merleau-Ponty, 1968, 135), is itself always an object to some *other* subject, so that the simple distinction between subject and object is confounded and "we no longer know which sees and which is seen" (139). The phenomenological grounding of the subject is thus indicative of the close interplay of subject and object in the lifeworld. Generally speaking then, what the move from classical thinking to phenomenology essentially entails is an internalization of the relations among subject, object, and space.

5. The dimension of depth

The link between the lifeworld and the quantum world should already be broadly evident. With the former, the classical continuum is supplanted by an internally constituted space of overlapping entities featuring the intimate interaction of subject and object. A more specific articulation of the phenomenological response to the problem of quantum gravity can be derived from another work of Merleau-Ponty. In his essay "Eye and Mind" (1964), his concept of *depth* provides an account of dimensionality that permits us to better understand the limitations of Cartesian space and to surpass them.

For Descartes, notes Merleau-Ponty, a dimension is an extensive continuum entailing "absolute positivity" (1964, 173). Descartes' assumption is that space simply is *there*, that it subsists as a positive presence possessing no folds or nuances; no shadows, shadings, or subtle gradations; no internal dynamism. Space is thus taken as the utterly explicit openness that constitutes a field of strictly external relations wherein unambiguous measurements can be made. Along with height and width, depth is but the third dimension of this hypostatized three-dimensional field. Merleau-Ponty contrasts the Cartesian view of depth with the animated depth of the lifeworld, where we discover in the dialectical action of perceptual experience a paradoxical interplay of the visible and invisible, of identity and difference:

> The enigma consists in the fact that I see things, each one in its place, precisely because they eclipse one another, and that they are rivals before my sight precisely because each one is in its own place. Their exteriority is known in their envelopment and their mutual dependence in their autonomy. Once depth is understood in this way, we can no longer call it a third dimension. In the first place, if it were a dimension, it would be the *first* one; there are forms and definite planes only if it is stipulated how far from me their different parts are. But a *first* dimension that contains all the others is no longer a dimension, at least in the ordinary sense of a *certain relationship* according to which we make measurements. Depth thus understood is, rather, the experience of the reversibility of dimensions, of a global 'locality' — everything in the same place at the same time, a locality from which height, width, and depth [the classical dimensions] are abstracted. (1964, 180)

Speaking in the same vein, Merleau-Ponty characterizes depth as "a single dimensionality, a polymorphous Being," from which the Cartesian dimensions of linear extension derive, and "which justifies all [Cartesian dimensions] without being fully expressed by any" (1964, 174). The dimension of depth is "both natal space and matrix of every other existing space" (176).

Merleau-Ponty proceeds to explore the depth dimension via the artwork of Cézanne. Through the painter, he demonstrates that primal dimensionality is *self-containing*. For Cézanne works with a visual space that is not abstracted from its content but flows unbrokenly into it. Or, putting it the other way around, the contents of a Cézanne painting overspill their boundaries *as* contents so that, rather than merely being contained like objects in an empty box, they fully participate in the containment process. Inspired by Cézanne's paintings, Merleau-Ponty comments that "we must seek space and its content *as* together" (1964, 180).

Merleau-Ponty also makes it clear that the primal dimension engages embodied subjectivity: the dimension of depth "goes toward things from, as starting point, this body to which I myself am fastened" (1964, 173). In commenting that, "there are forms and definite planes only if it is stipulated how far from *me* their different parts are" (180; italics mine), Merleau-Ponty is conveying the same idea. A little later, he goes further:

> The painter's vision is not a view upon the *outside*, a merely "physical-optical" relation with the world. The world no longer stands before him through representation; rather, it is the painter to whom the things of the world give birth by a sort of concentration or coming-to-itself of the visible. Ultimately the painting relates to nothing at all among experienced things unless it is first of all 'autofigurative'… The spectacle is first of all a spectacle of itself before it is a spectacle of something outside of it. (1964, 181)

In this passage, the painting of which Merleau-Ponty speaks, in drawing upon the originary dimension of depth, draws in upon itself. Painting of this kind is not merely a signification of objects but a concrete *self*-signification that surpasses the division of object and subject.

In sum, the phenomenological dimension of depth as described by Merleau-Ponty, is (1) the "first" dimension, inasmuch as it is the source of the Cartesian dimensions, which are idealizations of it; it is (2) a self-containing dimension, not merely a container for contents that are taken as separate from it; and it is (3) a dimension that blends subject and object concretely, rather than serving as a static staging platform for the objectifications of a detached subject. Therefore, in realizing depth, we go beyond the concept of space as but an inert container and come to understand it as an aspect of an indivisible cycle of lifeworld action in which the "contained" and "uncontained"—object and subject—are integrally incorporated.

Have we not previously encountered an action cycle of this kind? In Section 3, we considered the fundamental "atom of process" that lies at the core of quantum mechanics: $\hbar$, the *quantum of action*. The discontinuity associated with quantized microphysical action bespeaks the fact that this indivisible circulation undermines the infinitely divisible classical continuum, and, along with it, the idealized objects purported to be enclosed in said continuum and the idealized subject alleged to stand outside it. We know that it is only through probabilistic artifice that microphysical action can be accommodated while maintaining the old trichotomy, and that this stratagem is only effective above the Planck length, where the full impact of quantized action can be avoided. In addressing the problem of quantum gravity, however, no longer can we remain safely above the Planck length. And it is at or below the Planck scale that quantized action is simply unmanageable as a circumscribed object contained within an analytical continuum from which the analyst is detached. The action in question entails the *indivisible transpermeation* of object, space, and subject—something utterly unthinkable when adhering to the classical formula. Yet just such a dialectic defines the depth dimension as described by Merleau-Ponty. Broadly speaking, this suggests that, when the problem of quantum gravity can no longer be deferred in the quest for unification, science can no longer conduct its business as usual. Instead, a whole new basis for scientific activity is required, a new way of thinking about object, space, and subject, one cast along the lines of Merleau-Pontean depth.

6. Phenomenology, topology, and the Klein bottle

I have intimated that the Planckian action integral to the account of quantum gravity is better understood when approached from the standpoint of phenomenological philosophy than from that of traditional philosophy. Whereas the Platonic-Cartesian intuition of object-in-space-before-subject makes it impossible to come to grips with the discontinuity and intimate subject-object interaction of the Planckian realm, Merleau-Ponty's depth dimensional intuition gives us the insight we need. It is obvious, however, that a full-fledged phenomenology of quantum gravity must be delivered in comprehensive detail, not just as a broad philosophical sketch. This task was undertaken in *The Self-Evolving Cosmos* (Rosen, 2008a). In the present introductory paper, I will limit myself to a synopsis of that work. But first, in the section at hand, I want to pave the way for the synopsis by turning to *topology*. This qualitative field of mathematics will help flesh out the connection between the philosophical notion of depth and the more sharply defined concepts and phenomena of theoretical physics.

To conventional thinking, topology is generally defined as the branch of mathematics that concerns itself with the properties of geometric figures that stay the same when the figures are stretched or deformed. In algebraic topology, structures from abstract algebra are employed to study topological spaces. A more concrete approach to topology is exemplified by the practical experiments of mathematician Stephen Barr (1964). In either case, however, the underlying philosophical default setting tacitly operates, with topological structures regarded strictly as objects under the scrutiny of a detached analyst. Yet, in Heidegger's enigmatic invocation of a “topology of Being” (1954/1971, 12), and in Merleau-Ponty's reference to “topological space as … constitutive of life” (1968, 211), there is a first intimation of a phenomenologically-based, non-objectifying topology. As a matter of fact, when Merleau-Ponty metaphorically describes this topological space as “the image of a being that … is older than everything and ‘of the first day’” (210), we are reminded of the concept of dimension he had outlined in his earlier work: the concept of *depth* (1964). Can we sharpen our focus on the depth dimension by going further with topology? A well-known topological curiosity appears especially promising in this regard: the *Klein bottle*.

Elsewhere, I have used the Klein bottle to address a variety of philosophical issues (see, for example, Rosen, 1994, 1997, 2004, 2006, 2014). For our present purpose, we begin with a simple illustration.

Fig. 1 is my adaptation of communication theorist Paul Ryan's linear schemata for the Klein bottle (1993, 98). According to Ryan, the three basic features of the Klein bottle are “part contained,” “part uncontained,” and “part containing.” Here we see how the part contained opens out (at the bottom of the figure) to form the perimeter of the container, and how this, in turn, passes over into the uncontained aspect (in the upper portion of Fig. 1). The three parts of this structure thus flow into one another in a continuous, self-containing movement that flies in the face of the classical trichotomy of contained, containing, and uncontained—symbolically, of object, space, and subject. But we can also see an aspect of *dis*continuity in the diagram. At the juncture where the part uncontained passes into the part contained, the structure must intersect itself. Would this not break the figure open, rendering it *simply* discontinuous? While this is indeed the case for a Klein bottle conceived as an object in ordinary space, the true Klein bottle actually enacts a *dialectic* of continuity and discontinuity, as will become clearer in further exploring this peculiar structure. We can

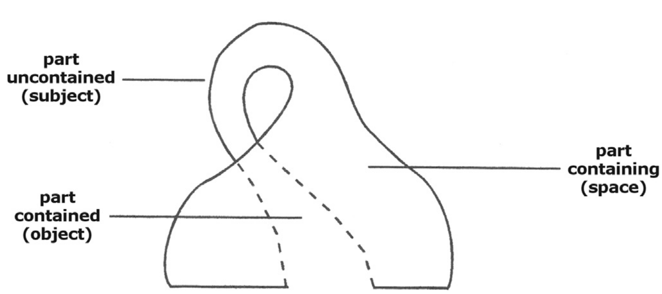

Fig. 1. Parts of the Klein bottle (after Ryan, 1993, 98).

say then that, in its highly schematic way, the one-dimensional diagram lays out symbolically the basic terms involved in the “continuously discontinuous” dialectic of depth. Depicted here is the process by which the three-dimensional object of the lifeworld, in the act of containing itself, is transformed into the subject. This blueprint for phenomenological interrelatedness gives us a graphic indication of how the mutually exclusive categories of classical thought are surpassed by a threefold relation of mutual inclusion. It is this relation that is expressed in the primal dimension of depth.

When Merleau-Ponty says that the “enigma [of depth] consists in the fact that I see things… precisely because they eclipse one another,” that “their exteriority is known in their envelopment,” he is saying, in effect, that the peremptory division between the inside and outside of things is superseded in the depth dimension. Just this supersession is embodied by the Klein bottle. What makes this topological surface so surprising from the classical standpoint is its property of one-sidedness. More commonplace topological figures such as the sphere and the torus are two-sided; their opposing sides can be identified in a straightforward, unambiguous fashion. Therefore, they meet the classical expectation of being closed structures, structures whose interior regions (“parts contained”) *remain* interior. In the contrasting case of the Klein bottle, inside and outside are freely reversible. Thus, while the Klein bottle is not simply an open structure, neither is it simply closed, as are the sphere and the torus. In studying the properties of the Klein bottle, we are led to a conclusion that is paradoxical from the classical viewpoint: this structure is both open *and* closed. The Klein bottle therefore helps to convey something of the sense of dimensional depth that is lost to us when the fluid lifeworld relationships between inside and outside, closure and openness, continuity and discontinuity, are overshadowed in the Cartesian experience of their categorical separation.

However, must the self-containing one-sidedness of the Klein bottle be seen as involving the *spatial* container? Granting the Klein bottle's *symbolic* value, could we not view its inside-out flow from “part contained” to “part containing” merely as a characteristic of an object that itself is simply “inside” of space, with space continuing to play the classical role of that which contains without being contained? In other words, despite its suggestive quality, does the Klein bottle not lend itself to classical idealization as a mere object-in-space just as much as any other structure?

A well-known example of a one-sided topological structure that indeed can be treated as simply contained in three-dimensional space is the Moebius strip. Although its opposing sides do flow into each other, this is classically interpretable as but a global property of the surface, a feature that depends on the way in which the surface is enclosed in space but one that has no bearing on the closure of space as such. Here the topological structure of the Moebius, the particular way its boundaries are formed (one end of the strip must be twisted before joining it to the other), can be seen as unrelated to the sheer boundedness of the infinitely many structureless point elements tightly packed into the spatial continuum itself. So, despite the one-sidedness of the Moebius strip, the three-dimensional space in which it is embedded can be taken as retaining its simple closure. The maintenance of a strict distinction between the global properties of a topological structure and the local structurelessness of its spatial context is mathematics' way of upholding the underlying classical relation of object-in-space. Given that the Moebius strip does lend itself to drawing said categorical distinction, can we say the same of the Klein bottle? Although conventional mathematics answers this question in the affirmative, I will suggest the contrary.

The schematic representation of the Klein bottle provided by Fig. 1 shows that it possesses the curious property of passing through itself. When we consider the actual construction of a Klein bottle in three-dimensional space (by joining one boundary circle of a cylinder to the other from the inside), we are confronted with the fact that no structure can penetrate itself without cutting a hole in its surface, an act that would render the model topologically imperfect (simply discontinuous). So the Klein bottle cannot be assembled effectively when one is limited to three dimensions.

Mathematicians observe that a form that penetrates itself in a given number of dimensions can be produced without cutting a hole if an *added* dimension is available. The point is imaginatively illustrated by Rudolf Rucker (1977). He asks us to picture a species of "Flatlanders" attempting to assemble a Moebius strip, which is a lower-dimensional analogue of the Klein bottle. Rucker shows that, since the reality of these creatures would be limited to *two* dimensions, when they would try to make an actual model of the Moebius, they would be forced to cut a hole in it. Of course, no such problem with Moebius construction arises for us human beings, who have full access to three external dimensions. It is the making of the Klein bottle that is problematic for us, requiring as it would a *fourth* dimension. Try as we might we find no fourth dimension in which to execute this operation.

However, in contemporary mathematics, the fact that we cannot create a proper model of the Klein bottle in three-dimensional space is not seen as an obstacle. The modern mathematician does not limit him- or herself to the concrete reality of space but feels free to invoke any number of higher dimensions. Notice though, that in summoning into being these extra dimensions, the mathematician is extrapolating from the known three-dimensionality of the concrete world. This procedure of dimensional proliferation is an act of abstraction that presupposes that the nature of dimensionality itself is left unchanged. In the case of the Klein bottle, the "fourth dimension" required to complete its formation remains an *extensive continuum*, though this "higher space" is acknowledged as but a formal construct; the Klein bottle per se is regarded as an abstract mathematical object simply contained in this hyperspace (whereas the sphere, torus, and Moebius strip are relatively concrete mathematical objects, since tangibly perceptible models of them may be successfully fashioned in three dimensions). We see here how the conventional analysis of the Klein bottle unswervingly adheres to the classical formulation of object-in-space. Moreover, whether a mathematical object must be approached through hyperdimensional abstraction or it is concretizable, the mathematician's attention is always directed outward toward an object, toward that which is cast before his or her subjectivity. This is the aspect of the classical stance that takes subjectivity as the detached position from which all objects are viewed (or, better perhaps, from which all is viewed as object); here, never is subjectivity *as such* opened to view. Thus the posture of contemporary mathematics is faithfully aligned with that of Plato, Descartes, and Newton in whatever topic it may be addressing. Always, there is the mathematical object (a geometric form or algebraic function), the space in which the object is contained, and the seldom-acknowledged uncontained subjectivity of the mathematician who is carrying out the analysis.

Now, in his study of topology, Barr advised that we should not be intimidated by the "higher mathematician …. We must not be put off because he is interested only in the higher abstractions: we have an equal right to be interested in the tangible" (1964, 20). The tangible fact about the Klein bottle that is glossed over in the higher abstractions of modern mathematics is its *hole*. Because the standard approach has always presupposed extensive continuity, it cannot come to terms with the inherent *dis*continuity of the Klein bottle created by its self-intersection. Therefore, all too quickly, "higher" mathematics circumvents this concrete hole by an act of abstraction in which the Klein bottle is treated as a properly closed object embedded in a hyper-dimensional continuum. Also implicit in the mainstream approach is the detached subjectivity of the mathematician before whom the object is cast. I suggest that, by staying *with* the hole, we may bring into question the classical intuition of object-in-space-before-subject.

Let us look more closely at the hole in the Klein bottle. This loss in continuity is *necessary*. One certainly could make a hole in the Moebius strip, torus, or any other object in three-dimensional space, but such discontinuities would not be necessary inasmuch as these objects could be properly assembled in space *without* rupturing them. It is clear that whether such objects are cut open or left intact, the closure of the space containing them will not be brought into question; in rendering these objects discontinuous, we do not affect the assumption that the space in which they are embedded is simply continuous. With the Klein bottle it is different. Its discontinuity does speak to the supposed continuity of three-dimensional space itself, for the necessity of the hole in the bottle indicates that space is unable to contain the bottle the way ordinary objects appear containable. We know that if the Kleinian "object" is properly to be closed, assembled without merely tearing a hole in it, an "added dimension" is needed. Thus, for the Klein bottle to be accommodated, it seems the three-dimensional continuum itself must in some way be opened up, its continuity opened to challenge. Of course, we could attempt to sidestep the challenge by a continuity-maintaining act of abstraction, as in the standard mathematical analysis of the Klein bottle. Assuming we do not employ this stratagem, what conclusion are we led to regarding the "higher" dimension that is required for the completion of the Klein bottle? If it is not an extensive continuum, what sort of dimension is it? I suggest that it is none other than the dimension of depth adumbrated by Merleau-Ponty.

Depth is not a "higher" dimension or an "extra" dimension; it is not a fourth dimension that transcends classical three-dimensionality. Rather—as the "*first* dimension" (1964, 180), depth constitutes the dynamic *source* of the Cartesian dimensions, their "natal space and matrix" (176). Therefore, in realizing depth, we do not move away from classical experience but move back into its ground where we can gain a sense of the primordial process that first gives rise to it. The depth dimension does not complete the Klein bottle by adding anything to it. Instead, the Klein bottle reaches completion when we cease viewing it as an object-in-space and recognize it as the embodiment of depth. It is the Kleinian pattern of action (as schematically laid out in Fig. 1) that expresses the in-depth relations among object, space, and subject from which the old trichotomy is abstracted as an idealization. So it turns out that, far from the Klein bottle requiring a classical dimension for its completion, it is classical dimensionality that is completed by the Klein bottle, since—in its capacity as the embodiment of depth—the Klein bottle exposes the hitherto concealed ground of classical dimensionality. Here is the key to transforming our understanding of the Klein bottle so that we no longer view it as an imperfectly formed object in classical space but as the dynamic ground of that space: we must recognize that the hole in the bottle is a hole in classical space itself, a discontinuity that—when accepted in dialectical relation to continuity rather than evaded—leads us beyond the concept of dimension as Cartesian continuum to the idea of dimension as depth.

By way of summarizing the paradoxical features of the Klein bottle, I refocus on the threefold disjunction implicit in the standard treatment of the bottle: contained object, containing space, uncontained subject. (1) The contained constitutes the category of the bounded or finite, of the immanent contents we reflect upon, whatever they may be. These include empirical facts and their generalizations, which may be given in the form of equations, invariances, or symmetries. (2) The containing space is the contextual bounded*ness* serving as the means by which reflection occurs. (3)

The uncontained or unbounded is the transcendent agent of reflection, namely, the subject. It is in adhering to this classical trichotomy that the Klein bottle is conventionally deemed a topological object embedded in “four-dimensional space.” But the actual nature of the Klein bottle suggests otherwise. The concrete necessity of its hole indicates that, in reality, this bottle is not a mere object, not simply enclosed in a continuum as can be assumed of ordinary objects, and not open to the view of a subject that itself is detached, unviewed (uncontained). Instead of being contained in space, the Klein bottle may be described as *containing itself*, thereby superseding the dichotomy of container and contained. Instead of being reflected upon by a subject that itself remains out of reach, we may say that the self-containing Kleinian “object” is self-reflexive: it *flows back into* the subject thereby disclosing—not a detached *cogito*, but the dimension of depth that constitutes the dialectical lifeworld.

7. Phenomenological quantum gravity: a summary

In *The Self-Evolving Cosmos* (2008a), I offer a phenomenological rendition of quantum gravity accounting for the four forces of nature, the matter particles of physics' standard model, and the transformation of particles and fields in the course of cosmogony. Having demonstrated in the previous sections of the present paper why a unified physics requires phenomenological philosophy, my intention now is to show through a summary of *Cosmos* how the specific application of phenomenology can yield significant concrete results. A synoptic review of the results will be presented here. The reader is referred to the book itself for the more detailed arguments that support those findings.

As noted above, the primary “atom of process” in microphysics is ħ, the quantum of action associated with the emission of radiant energy. This quantized action takes the form of an odd spinning that Wolfgang Pauli modeled by using complex numbers. Musès (1976) suggested that Pauli's spin matrices for the electron are actually based on a kind of complex number or “hypernumber” that goes beyond Pauli's imaginary i: the hypernumber ε (defined as $\varepsilon^2 = +1$, but $\varepsilon \neq \pm 1$). What I demonstrate in *Cosmos* is that the geometric counterpart of ε is the Klein bottle. In the form of εħ, the Klein bottle is thus seen to implicitly embody the angular action that lies at the core of quantum mechanics. And this Kleinian spin is the basic building block of phenomenological quantum gravity.

In Pauli's matrices, ħ/2 is taken as the fundamental unit of electron spin. In fact, ħ/2 is the basis for determining the spin of *all* subatomic particles, fermions and bosons alike. Given the essential role played by spin in quantum mechanics and the underlying significance of the Klein bottle in said spin, I propose in *Cosmos* that all microworld dynamics arise from spin of the Kleinian kind: εħ/2.

Now, in Section 3 of the present paper, I offer a critique of what has been the favored approach to quantum gravity: string theory. One of the problems I note is that the theory's quantum gravitational equations lead to a vast multiplicity of possible solutions with no guiding principle by means of which the field can be narrowed. But if we take the vibratory pattern of the fundamental strings as essentially Kleinian in nature—with Kleinian spin not objectified but understood in its phenomenological depth—string theory can gain greater coherence. In fact, I demonstrate in *Cosmos* that by reformulating the theory in the context of topological phenomenology, it can be cast in a form that provides a detailed and definitive (albeit qualitative) account of quantum gravity, one that unambiguously yields the fundamental particles of the standard model. Let me summarize these findings.

In his further exploration of the hypernumber ε, Musès indicated a “higher epsilon-algebra” wherein “$\sqrt{\varepsilon_n}$ involves i_n, the subscripts of course referring to the $(n + 1)$th dimension since $i \equiv i_1$ already refers to D_2” (1968, 42). Bearing in mind the intimate relationship between ε and the Klein bottle, can Musès' implication of a dimensional hierarchy of hypernumber values be given topophenomenological expression? The Klein bottle does lend itself to such a generalization.

Mathematicians have investigated the transformations that result from bisecting topological surfaces. If the Klein bottle is bisected, cut down the middle, it will fall into a pair of oppositely-oriented Moebius strips. Next, bisecting the one-sided Moebius strip, a two-sided lemniscatory surface will be produced, its sides being related enantiomorphically (i.e., as mirror opposites). Finally, cutting the lemniscate down the middle yields interlocking lemniscates. The transformation brought about by this bisection is clearly the last one of any significance, since additional bisections—being bisections of lemniscates, can only produce the same result: interlocking lemniscates. The bisection series is completed then when we obtain interlocking lemniscates, a structure termed the *sub-lemniscate*. By experimenting with the bisection of the Klein bottle in this way, a closed family of four nested topological structures is discovered (Fig. 2).

In *Cosmos*, dimensional differences among the four members of the bisection series are studied phenomenologically. While to ordinary observation each member appears as but a two-dimensional surface in three-dimensional space, phenomenological reflection leads to the insight that each actually constitutes a depth-dimensional lifeworld unto itself. Whereas the Klein bottle is three-dimensional, its nested correlates are of progressively lower dimension: the Moebius is two-dimensional, the lemniscate is one-dimensional, and the sub-lemniscate is zero-dimensional. This account of several different topodimensional lifeworlds embedded within each other is consistent with the hierarchy of ε-like spin structures suggested by Musès.

Table 1, the topodimensional spin matrix, gives the ε-based counterpart of the topological bisection series. The three-dimensional Kleinian spinor is written ε_{D3}, with lower-dimensional members of the tightly knit spin family designated ε_{D2}, ε_{D1}, and ε_{D0} (corresponding to the Moebial, lemniscatory, and sub-lemniscatory circulations, respectively). These terms are arrayed on the principal diagonal of the matrix (extending from upper left to lower right). The interrelationships among the four principal matrix elements, taken two at a time, are reflected in the elements appearing off the main diagonal.

Generally speaking, Table 1 unpacks the dialectical structure of topodimensional interrelations. In keeping with the “musical” implications of string theory, we may regard topodimensional action

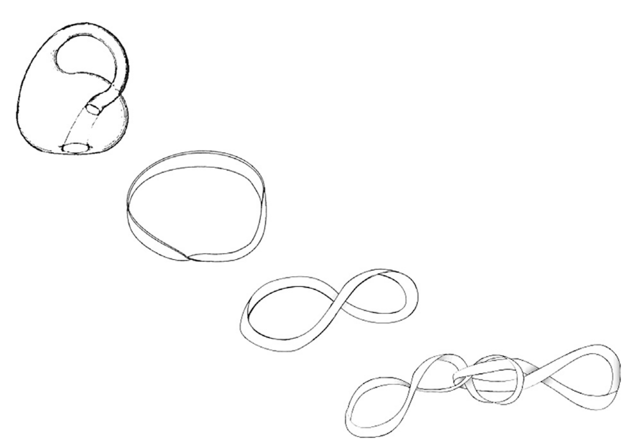

Fig. 2. Topological bisection series. From top to bottom: Klein bottle, Moebius strip, lemniscate, sub-lemniscate.

Table 1
Interrelational matrix of topodimensional spin structures.

ε_{D0}	$\varepsilon_{D0}/\varepsilon_{D1}$	$\varepsilon_{D0}/\varepsilon_{D2}$	$\varepsilon_{D0}/\varepsilon_{D3}$
$\varepsilon_{D1}/\varepsilon_{D0}$	ε_{D1}	$\varepsilon_{D1}/\varepsilon_{D2}$	$\varepsilon_{D1}/\varepsilon_{D3}$
$\varepsilon_{D2}/\varepsilon_{D0}$	$\varepsilon_{D2}/\varepsilon_{D1}$	ε_{D2}	$\varepsilon_{D2}/\varepsilon_{D3}$
$\varepsilon_{D3}/\varepsilon_{D0}$	$\varepsilon_{D3}/\varepsilon_{D1}$	$\varepsilon_{D3}/\varepsilon_{D2}$	ε_{D3}

as inherently vibratory in nature. The principal diagonal of the table contains a depth-dimensional series of fundamental vibrations or tones, and these four principal terms are coupled to each other two at a time by six pairs of overtone-undertone intervals related to each other in the mirror-opposed fashion of enantiomorphs. The dimensional overtone ratios are the values extending below the fundamental tones, whereas the undertone ratios are the values appearing to the right of the fundamentals. (In *Cosmos*, the topodimensional action matrix is seen as analogous to the old Pythagorean table, which is portrayed as an expanding series of musical intervals, with fundamental tones on the principal diagonal, flanked by overtones and undertones.)

Consider in Table 1 the two principal tones of highest dimensionality: ε_{D2} and ε_{D3}. These matrix elements are linked by the overtone and undertone given in the two corresponding non-principal cells, $\varepsilon_{D3}/\varepsilon_{D2}$ and $\varepsilon_{D2}/\varepsilon_{D3}$ (respectively). The enantiomorphically-related coupling cells in question are the depth-dimensional counterparts of the concretely observable, oppositely oriented Moebius strips which, when glued together, form the Klein bottle. Taken strictly as a principal matrix element, the depth-dimensional Moebius vibration is the spin structure that constitutes the two-dimensional lifeworld (ε_{D2}). But when we shift our view of the Moebius, consider it in relation to higher, Kleinian dimensionality, a kind of "doubling" takes place in which the ε_{D2} singular Moebius spin structure becomes a pair of asymmetric, mirror-opposed twins, $\varepsilon_{D3}/\varepsilon_{D2}$ and $\varepsilon_{D2}/\varepsilon_{D3}$. It is through the fusion of these dimensional enantiomorphs that Kleinian dimensionality is crystallized. Since the Table 1 matrix indicates that all four principal dimensionalities or fundamental tones are interrelated by accompanying off-diagonal overtone-undertone pairs, we can draw the general conclusion that higher dimensions emerge through processes of enantiomorphic fusion (this is fully detailed in *Cosmos*).

The process of dimensional generation can be clarified in broad terms by relating it to a reverse movement through the bisection series wherein topological structures are not divided but glued together. To begin, we imagine the fusion of interlocking lemniscates that yields the single lemniscate. This corresponds to the generation of the one-dimensional lifeworld (ε_{D1}). Next, we picture the enantiomorphically-related sides of the two-sided lemniscate merging to form the one-sided Moebius structure, this being associated with the genesis of the two-dimensional lifeworld (ε_{D2}). Finally, we imagine Moebius enantiomorphs fusing to produce the Klein bottle, which corresponds to the evolution of our three-dimensional lifeworld (ε_{D3}). With each fusion, a lower-dimensional lifeworld is absorbed by a world of higher dimension, taken into it in such a way that the lower dimension is concealed. In the end, we have three lower-dimensional vibratory structures concealed within the three-dimensional Kleinian vibration, much as lower dimensions are hidden by becoming "curled up" within visible 3 + 1-dimensional space-time in the conventional string theoretic account of dimensional cosmogony. It turns out, in fact, that the phenomenological approach arrives at the *same* total number of dimensions as does the conventional theory.

What I demonstrate in *Cosmos* is that the depth-dimensional Kleinian spinor, ε_{D3}, is not itself an extended three-dimensional space, but is a quantized three-dimensional blend of space and time that first gives birth to our familiar 3 + 1-dimensional space-time (the Kleinian spinor is a "natal space," to echo Merleau-Ponty's metaphor). In like manner, the two-dimensional Moebius spinor (ε_{D2}) would spin out a 2 + 1-dimensional space-time, the lemniscatory spinor (ε_{D1}) would send forth a 1 + 1-dimensional space-time, and the sub-lemniscatory spinor (ε_{D0}) would project a 0 + 1-dimensional space-time. A simple summation of projected space-time dimensions gives us a total of ten, with the six lower dimensions—(2 + 1) + (1 + 1) + (0 + 1)—being hidden like Matryoshka dolls within the larger 3 + 1-dimensional space-time. This picture of overall ten-dimensionality, with six dimensions concealed, accords with the basic account provided by string theory. Thus we may say that our four depth-dimensional spinors spin out the ten space-time dimensions of string theory.[1]

Yet despite the general agreement between conventional and phenomenological interpretations of string theory, important differences exist. Mainstream theorists have approached cosmogony by adopting the concept of *symmetry breaking*. In this narrative, the four forces of nature are conceived as vibrating strings that initially existed in a purely symmetric ten-dimensional space scaled around the Planck length. Subsequently, the perfect primordial symmetry was spontaneously broken by a dimensional bifurcation in which four of the original dimensions expanded to produce the visible universe we know today, with the other dimensions remaining hidden. Coupled with this was the breaking of force-field symmetry to create the appearance of irreconcilable differences among the forces.

However, while the foregoing account of cosmogony incorporates both dimensional and force-field symmetry breaking, the two are not precisely aligned with each other in the theoretical reckoning. This reflects the fact that contemporary theorists have been unable to articulate a detailed geometric rendering of cosmic evolution. For the geometric program fully to be realized, the physical events described in the standard and inflationary models of cosmic development would need to be specifically expressible as dimensional events. What Heinz Pagels noted twenty years ago in discussing the extra-dimensional (Kaluza-Klein) interpretation of cosmogony remains true today: "No one has yet been able to find a realistic Kaluza-Klein theory which yields the standard model" (1985, 328). In the string-theoretic application of Kaluza-Klein theory, one obvious reason for this limitation is the absence of a conceptual principle that could guide the analyst to unambiguous solutions of the ten-dimensional general equations, solutions specifying the exact shapes of the hidden dimensions that would correspond to the physical facts of the standard model. Of course, if the prevailing theory cannot tell us what the dimensional structures are that correspond to physical reality, it can hardly inform us on how these dimensions develop. In point of fact, there is really no positive feature intrinsic to the theory that provides for the evolution of dimensions. From what I can tell, the only reason dimensional bifurcation is assumed to have taken place at all is that theorists must somehow account for the present inability to observe six of the ten dimensions needed for a consistent rendering of quantum gravity (one that avoids untenable probability values).

Smolin seems to put his finger on the underlying problem in calling attention to the "wrong assumption" physicists "are all making" when they present the "whole history of constant motion and change … as something static and unchanging" (2006,

[1] With the extension of string theory known as *M-theory*, eleven dimensions are actually entailed, though the eleventh dimension is not like the other ten. This "extra" dimension in fact may be interpreted as intimating the depth dimension. See *The Self-Evolving Cosmos* (2008a).

256–57). When authentic change is thus denied, it is not surprising that no natural, parsimonious way of accounting for cosmogony is forthcoming. Conventional string theory well exemplifies this adherence to the classical intuition of changelessness in the primacy it gives to the notion of symmetry. It is in assuming an initial state of "perfect symmetry" that theorists must resort to the artifice of "spontaneous symmetry breaking," an alleged event that—far from being a natural consequence of the purely symmetric theory—is gratuitously invoked without a compelling explanation of its basis.

The inherent dynamism of phenomenological string theory affords a way out of the impasse. Instead of artificially appending asymmetry to a primordially perfect symmetry, a *dialectic* of symmetry and asymmetry is offered that permits an unequivocal, intrinsically meaningful account of the evolving forces of nature. This principle of "synsymmetry" (Rosen, 1975, 1994, 2006, 2008a) is implicit in the topological bisection series and its associated topodimensional spin matrix (Table 1).

For a simple illustration, consider the Moebius strip. It arises from the fusion of mirror-opposed, asymmetrically-related sides of the lemniscate. We can say that, through this union of opposites, the asymmetry of lemniscatory sides is rendered symmetric. However, while the Moebius can be deemed symmetric vis-à-vis the fused lemniscatory sides that constitute it, at the same time it is itself a member of an enantiomorphically asymmetric pair whose own fusion produces the Klein bottle. Generally speaking, we may conclude that the members of our topodimensional family are neither simply asymmetric nor simply symmetric, but *syn*symmetric: a given member combines symmetry and asymmetry in such a way that it is symmetric in relation to its lower-dimensional counterpart and asymmetric in relation to its higher one (the sublemniscate is an exception to this, since it has no lower-dimensional counterpart). I propose that the synsymmetry concept, viewed dynamically in terms of enantiomorphic fusion events, constitutes a guiding principle for cosmogony. The forces and particles of nature evolve by a general process wherein asymmetric dimensional enantiomorphs fuse to create a dimensional symmetry that at once inherently gives way to new asymmetry. My topophenomenological interpretation of cosmogony is detailed in *Cosmos*. Presently, I will restrict myself to a synoptic sketch.

What I am suggesting is that a full account of the elementary forces of string theory may be afforded by embedding the theory in the matrix of primordial spin structures given in Table 1. This matrix constitutes a special application of the hypernumber idea, one that provides a highly specific rendition of primordial spin action. The topodimensional array of four fundamental spinors (shown on the principal diagonal of the matrix) can be directly associated with the four types of gauge bosons found in nature. The gauge-boson correlates of Table 1 are displayed in Table 2. What is the basis of these correlations?

We know that Table 1 signifies a process of generation in which higher topological dimensions evolve from lower ones. The facts of *physical* evolution lend themselves to straightforward, one-to-one correlation with topogenetic process. The first force particle to "freeze out" of the Big Bang's hot primordial soup is the hypothesized graviton, G. The graviton of Table 2 is associated with ε_{D0}, the zero-dimensional sub-lemniscatory action of Table 1, which can be written $\varepsilon_{D0}(\hbar/2)$ to give expression to subatomic particle spin; thus, $G \equiv \varepsilon_{D0}(\hbar/2)$. Next to separate itself from the primordial chaos is the strong gauge boson, g, and we relate it to ε_{D1} lemniscatory action, writing $g \equiv \varepsilon_{D1}(\hbar/2)$. Then the weak force emerges, given by the boson pair W and Z, which we identify with $\varepsilon_{D2}(\hbar/2)$. When the three orders of lower-dimensional gauge bosons have "frozen out," what remains is γ, the photon, topodimensionally expressed as $\varepsilon_{D3}(\hbar/2)$.

Having focused our attention on the principal terms or "fundamental tones" of our matrices, let us now inquire into the physical significance of the "overtone-undertone" couplings appearing off the principal diagonals. In Table 1, these are the topodimensional enantiomorphs whose synsymmetric fusions drive the process of dimensional generation. The overtone-undertone couplings appear in Table 2 as enantiomorphically-related boson ratios. It is from their interactions that the primary gauge bosons emerge. Since nature's force fields evolve by a process in which the universe expands, boson-ratio fusion may be regarded as impelling said expansion. I conjecture accordingly that these primordial boson ratio interactions, which are not themselves directly observable, comprise the mysterious "dark energy" said to fuel the accelerated expansion of the cosmos.

In phenomenological string theory, boson-ratio interaction not only accounts for the generation of the four kinds of gauge bosons, but for the production of the 12 fermions of the standard model as well. The six pairs of ratios involved in distilling the bosons also interact to yield the six pairs of fermions (three lepton pairs and three quark pairs). Geometrically speaking, the fermions function as "dimensional bounding elements," local features of global bosonic dimensionality, with local and global aspects intimately interwoven (in keeping with Merleau-Ponty's notion of the depth dimension as a "global 'locality'"; see Section 5). Needless to say, this requires clarification, but I will not elaborate further on it here (see *Cosmos*). I will only suggest that the purely geometric account of boson-fermion interrelatedness I am proposing obviates the need for the unparsimonious and unsubstantiated postulation of particle "super-partners" given in the notion of "supersymmetry."

Table 2
Spin matrix of gauge bosons. G is the graviton; g is the strong gauge boson; W,Z is the weak gauge boson particle pair; and γ is the photon.

G	G/g	G/(W, Z)	G/γ
g/G	g	g/(W, Z)	g/γ
(W, Z)/G	(W, Z)/g	W, Z	(W, Z)/γ
γ/G	γ/g	γ/(W, Z)	γ

8. Conclusion

To make the case for why natural science needs phenomenological philosophy, I have focused on what has come to be known as the "king of the sciences," the discipline of physics. It is physics that all other natural sciences (and many social sciences) have adopted as their paradigm. And it is physics—considered the most advanced and refined of sciences—in which the necessity for a phenomenological approach becomes most obvious. In this paper, I have shown that the refinement of physics that was to bring its long-sought unity ultimately reached the point (in the 1970s) where the facts of the Planck world could no longer be avoided effectively. And it is when we cross the Planckian threshold that objectivist philosophy must be left behind and a philosophical stance adopted that unites subject and object as sub-Planckian reality demands: the phenomenological stance.

Because I believe the challenge of quantum gravity provides the clearest evidence of the need for phenomenology in theoretical science, I have chosen to highlight this challenge in my introduction to our Special Issue. Here the reader is able to see at the outset that, in the key field of unification physics, regrounding natural science in a phenomenological approach is indispensable for solving science's own problems. In the pages that follow, you will find many other examples of the importance of phenomenology to the natural sciences. There are additional works on physics in this Special Issue, and a number of papers on the life sciences, mathematics, and (bio) semiotics. A previous Special Issue of this journal (Simeonov et al., 2013) already paved the way for what is presently set forth. There too, the Newtonian paradigm was called into question (see Gare, 2013) and elements of phenomenological thinking were in evidence (see Matsuno, 2013; Simeonov 2013). In the Issue now before you, phenomenological philosophy takes center stage and its relations to the natural sciences are examined in a comprehensive, thoroughgoing manner. I trust the reader will enjoy the rich assortment of innovative explorations that carry us beyond the obsolete formula of object-in-space-before-subject into exciting new territory.

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