# The Possibility for Answers from Physics

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Abstract:

When considering the question of what is possible to learn in Physics, we are grappling with issues of what is known, what is unknown, and what is knowable. To an extent, this involves weeding out meaningless or misleading questions and nurturing those questions which will lead us to a greater understanding of what is happening in the universe. But often such a determination rests on finding a broad enough framework to accommodate known factors emerging from different disciplines. It is my belief that it is overly simplistic to seek ideas that reconcile Relativity and Quantum Mechanics in the form of a Quantum Gravity Theory, if what we really require is a broader framework. This paper offers thoughts on what shape that framework must have, and how we can pin down the details of its structure. Ultimately; this reveals something about the limits of what is knowable by studying Physics, and what we can learn from Science in general.

Introduction:

Understanding is not simply knowledge of facts or information, but rather a way of making sense out of what is observed or known. While it is reasonable to assert that understanding is more a matter of cognition than hard science, I champion a view in this paper that it is properly the purview of Physics to discover and elucidate broad principles by which areas of knowledge about the universe can be understood. Therefore the question "What's ultimately possible in Physics?" is answerable mainly in terms of how we can develop an understanding about things that are currently unknown - both by expanding the breadth of our knowledge and by evolving or developing better models by which what we know can be understood. The fact there will always be things that exist in reality which are not possible to observe or verify through experiments does not keep us from wanting to understand the fundamental truths underlying what we do know, but many challenges await physicists who seek such an understanding.

Perhaps the greatest challenge of all is the matter of distinguishing facts and the knowledge of facts from conjectures, theories, or concepts we label as natural law. Alfred Korzybski, father of General Semantics, said "The word is not the thing" and "the map is not the territory." For Physics, we can add to this "The equation is not the phenomenon we are using Math to model." Instead; an equation is a convenient abstraction, or shorthand for the understanding represented by our model or theory, and not the physical reality itself. It is a mathematical model – no more. I am not saying there is no basis for what Eugene Wigner described as the "unreasonable effectiveness of Mathematics." There is. I believe that fundamental realities of Math may indeed be the basis for what we have come to call the Laws of Physics, to the extent that certain qualities must evolve in the abstract before they make an appearance in physical reality. However, many physicists treat equations as though they *are* the facts, and this is often erroneous. For example, Newton's "Laws of Motion and Gravitation" are very good approximations over a broad range of scale, but Einstein's equations must be used instead – when talking about cosmic distances or velocities approaching the speed of light.

Ergo; we must not, in our pursuit of fundamental truths, confuse models of natural law with the actual underlying principles or rules of the cosmos. So part of what must be determined is which ideas to retain as-is, and which ideas will need to be modified (or viewed as approximations) in order to further our understanding. To a degree, this involves figuring out whether certain aspects of a given theory can be modified or recast in some way that allows us to retain it's character in the area where the model's predictive capability is greatest, or whether there are fundamental incompatibilities in the framework for some theories - requiring additional basic principles in order to connect them to other theories. It is my belief that this latter possibility describes what is needed to formulate a common understanding for Relativity and Quantum Mechanics. That is; rather than trying to reconcile these two models, it may be more fruitful to acknowledge that there are fundamental incompatibilities in how these two theories are framed, and to find the connecting pieces which allow both to be retained as they are (more or less), while filling in the gaps that keep them apart.

It seems that we are already aware of some of the areas of knowledge that could serve to connect QM with Relativity, but have not yet recognized the existence of more general principles every bit as universal as these two pillars of Science. To a large degree, we already know the character of those principles through observation and experiment, but simply have not elevated that understanding to the same status accorded our two over-arching theories. It may well be that both Relativity and Quantum Mechanics are fundamental to our understanding, but they must be connected by other fundamental identities for us to see how they can be reconciled. The remainder of this paper will focus on what some of the other pillars might be, and what kind of structure emerges for Physics once we ascribe to those other principles the same kind of universality that we grant to the 'big two.' It is my belief that there are vast horizons to be explored in Physics, and that knowing what is ultimately possible depends less on finding a single unifying theory, and more on finding out how the pieces of what we know fit, in relation to each other piece.

A new approach:

If we simply ask "How can we reconcile Quantum theory with Relativity?" we may find ourselves disappointed. But if we recognize that we might be asking the wrong question, or might be asking the right question the wrong way, the real answers may become apparent rather quickly. A new approach would be to assume that we don't need to reconcile these two incompatible frameworks, but rather to find the other fundamental principles which connect them. In order to accomplish this, it may be helpful to review what the central concept is, from which each of these two branches of Physics emerge. Given the observable quantities of Matter, Energy, Space, and Time, Quantum theory comes out of unifying matter and energy, while Relativity comes out of unifying space and time. That is; if we assert that matter and energy are a single entity, with the two being alternate phases or aspects of the same thing, what emerges is Quantum Mechanics, where if we assume that space and time are a single entity, with the two being alternate phases or aspects of the same thing, what emerges is Relativity.

To continue down this road, one might think "What if we look to unifying all four observable quantities at once?" And some have asked "What if we unify the four fundamental forces instead?" This approach leads to grand unified theories, and theories of everything. I suggest that a better way may exist, however. If we are looking to unite Quantum theory and Relativity, it may be more fruitful to work at it through a stepwise approach, as with Electroweak theory being a tangible step toward a GUT, and then proceed to ultimate unification only once we have discovered and explicated additional fundamental unities. To this end, I suggest that it may be helpful to consider how other pairs of observables can be unified, and how these unified quantities relate to what we have already learned through the study of Physics, including Quantum Mechanics and Relativity. The question then becomes "Where do we begin looking for additional unities?" or "What observable quantities do we attempt to unify next?" One could be systematic, but it appears that we can start almost anywhere.

My new approach involves pairing up other quantities, and likewise asserting that they are two faces of the same thing. Is it reasonable to talk about matter-time or space-energy? The first is simply duration, in terms of the lifetime of particles and atomic nuclei, which appears as the half-life of a collection in the world of observables and measurements. We can find a ready equivalent to the second, space-energy, in what we call vacuum energy or dark energy, or what some call zero-point energy. This manifests in the form of pairs of virtual particles which appear to pervade space. The real understanding of this phenomenon eludes us, however, because the disparity between vacuum energy density estimates arising from Quantum theory, and those from Cosmology, differ by as much as 120 orders of magnitude! Frank Wilczek of MIT said, in an open letter to the Physics community, "Since vacuum energy density is central to both fundamental physics and cosmology, and yet extremely poorly understood, experimental research into its nature must be regarded as a top priority for physical science." I concur.

How about energy-time or matter-space – what are they? An energy-time equivalence may simply mean that the addition of more energy to a process allows us to do a given task in less time, while adding more time lets us do the same task with less energy – thus making the two interchangeable or equivalent. The fact that this is simply Newton's laws in action should not, of itself, prevent us from making such an association into the same sort of general principle as those underlying Quantum Mechanics and Relativity. How about matter-space; what might that be? We know that conventional matter is mostly empty space, so asking the question "how big is it?" is really a way of saying "how much space does this object contain?" Just as the ancient Chinese proverb suggests, it is the space contained that gives value to a vessel like a pot or jar, or to the windows, doors, and rooms of a house.

However; Constructive Mathematics asserts that the idea of an absolutely empty space having particular dimension is questionable, as it is the array of objects and observers contained by a volume (or other section) of space that allows us to make such a determination (either the size or the dimensionality of a space). For a clay pot or other vessel, the volume within contributes more to the dimension of the object than the thickness of its walls, but the walls hold the space open for other contents to fill. In this sense the size of objects is determined by the amount of space they contain, and the extent of a space is determined by the objects and/or observers contained therein, or containing it thereby, so that each defines the other. One could extend this idea with other known facts, and argue that since all measurements and observations are based upon electromagnetic waves, their properties determine dimensionality, which is the basis for what is called optical geometry.

So where does this leave us? It becomes apparent if we follow this through, that none of the fundamental principles at work operates alone. Even if size or scale is seen as arising from a relationship between matter and space (making the two observable quantities functionally equivalent) this does not prevent or deny the equivalence of matter and energy. Instead; it suggests that there is an equivalence between energy and space, as well. This continues for each combination uniting two of the four quantities – matter, energy, space, and time. Each unifying concept is made more meaningful when considered in relation to the others. So to matter-energy (or mass-energy) and space-time, we can add matter-space, matter-time, space-energy, and energy-time – making six fundamental unities, identities, or pillars in all. To some extent these are all meaningful formulations, so we don't have to stop at two unifying concepts. It is structurally equivalent to say "what happens if we assert that any one pair of observables is a single entity and see how the other two vary." This framework gives us plenty to explore.

The good news is that much of the work has already been done, and it is only a matter of reframing our existing knowledge in a different context. That is; there has been plenty of research into areas which should give insight into the nature of each such unification, and allow for a grand unification, once we admit the possibility that a broader framework is what's needed to create a more nearly encompassing understanding. One way to formulate this broader framework is to assert that matter, energy, space, and time, form a hierarchy where all matter is made from energy (or more simply; where matter *is* energy or an aspect thereof), energy arises as an aspect or a property of space, and space emerges as a manifestation of the extended nature of time. Let us examine this last idea more closely. While some have asserted that time is non-existent or illusory, especially in particle physics or the mathematical framework of quantum mechanics, I find this assertion questionable. Likewise; the idea that time is simply an emergent property of other aspects or quantities seems to have a shaky basis in my estimation.

The top winning entries in the Institute's last essay contest identify time as an illusory or emergent property, but I take a strongly opposing view. As with the essays by Carroll, Ellis, Markopoulou, and Vinson, I assert that time is indeed real and may in fact be more fundamental than some of the quantities from which it could supposedly emerge. I plan to champion this view at the upcoming Frontiers of Fundamental Physics conference, in connection with my presentation of a common basis for thermodynamic entropy and quantum non-locality. I can state here that decoherence theory clearly shows the inherent flow of time is not incompatible with Quantum Mechanics, nor does it have to be assumed constant for QM to work, but instead time arises as a direct consequence of irreversibility in any form of quantum measurement (including particle-particle interactions).

In that sense, time appears to be part of the fundamental nature of processes. Only the extended nature of time allows for processes to move from one step, or stage, to the next. And existence in time appears fundamental to the manifestation of objects and spaces, as well as processes. So there is a basis for a hierarchal view as a consequence of the nature of time as a directional process in entropy, in decoherence theory, and also in pre-geometric formulations such as that of Fotini Markopoulou. The gist here is that time may be more primal than space, energy, or matter, being a sort of prerequisite – a precursor or antecedent – to the existence of these quantities. It would explain a lot, if we assume that the geometry and other properties of space result from the extended nature of time.

In similar fashion; one can assert that the existence of energy and the laws of electrodynamics proceed from geometry and the properties of space or spacetime, and I have seen a number of examples of this recently. In his most recent work (soon to be published) Laurent Nottale devotes a whole chapter to the subject of how all the properties of gauge fields can arise directly from geometry. In a paper I read by José B. Almeida, monogenic functions are used in 5-d spacetime to derive Maxwell's equations and electrodynamics in both their classical and quantized forms. Working in a noncommutative framework, Alain Connes has demonstrated that the relative strengths of the fundamental forces and the structure of Quantum Field Theory can be shown to arise directly from geometry. These are only a few isolated examples, and there are plenty of others. As I stated in my opening comments, we must be careful we are not just worshipping Mathematics, when searching for or trying to utilize answers in Physics, making it a tool for our understanding rather than a proxy thereof. However; there are compelling reasons to believe that the underlying geometrical framework of physical reality shapes every aspect of it.

These last statements were emphatically voiced by Alex B. Mayer at the Crisis in Cosmology Conference last September. He insisted that Physics is about empirical data – observables and measurables – and that we should not be so taken with our models that we attempt to make the data fit. Instead; we must believe all the data, and not cast out samples unless we lack confidence in measurements because of possible errors. Nor was he of the opinion that Physics flows from Math, as he actively champions the opposite view. However; he appears convinced that the underlying geometry is the story, or a very large part of it. In his book "On the Geometry of Time" he states that "the nuclear strong force and gravitation are the identical phenomena (spacetime geometry in the context of wave mechanics) operating at different length scales." And though he offers a strong theoretical basis for that claim, he also points to empirical evidence – including the recent work of Jenkins et al. on correlations between nuclear decay rates and the Earth-Sun distance. How could one explain this kind of correlation, without recourse to varying fundamental constants, except as arising from geometry?

It is only fair, in any discussion of the contribution of Geometry to Physics, to mention the profound effect of Albert Einstein's reframing our concept of gravity. While Newton conceived of gravity as an invisible force acting upon massive objects, serving to draw them together, Einstein asserted that this effect arose because mass bearing objects deform the fabric of space-time. In other words, objects with mass cause space-time to curve, creating a gravimetric potential well, and this curvature has the effect of drawing objects together. Rather than simply superseding Newton's laws, however, it provides an expanded framework for them to operate in. This was an idea that sparked a revolution in Physics, which continues to this day. And it introduced the concept that the invisible fabric of space, and its geometry, might serve to create an observable force, gravity. Central to this formulation is the idea that space-time is a single entity. Minkowski stated that the idea of two separate entities, space and time, "would fade away into shadows" with only a space-time universe remaining. Mayer feels that we haven't taken these words seriously enough, however, and has re-visited Minkowski's formulation, suggesting that instead of being only a convenient mathematical abstraction, they tell us something important about the underlying fabric of reality.

Since the wave-particle duality and the idea that matter is made from energy are already well accepted, I won't waste time and space trying to prove matter and energy are the same. But it should at least be pointed out that Einstein's famous equation $E=mc^2$ gives us an exact equivalency, allowing us to calculate how much mass yields how much energy. And it should be made clear that even when energy is converted *into* mass, or is made into matter; it continues to have the properties of energy, or actually continues to *be* energy while it is matter. Therefore throughout its lifetime as bound energy which we observe as particles, atoms, and molecules; it continues to have the properties of energy, including a wave-like nature. Furthermore; Decoherence theory asserts that the wavefunction associated with a particle does not collapse when it interacts or decays, but rather is transferred to other particles and/or to its environment. That is; the wave-like and non-local aspect of unbound energy manifests through bound entities we know as particles, and couples them with each other and their environment, rather than disappearing when they are bound, or when they strike another object. Thus, the wave-like aspect of things is preserved and becomes a part of physical reality, rather than being supplanted by the particle-like aspect.

However; even the massless carriers of energy known as photons must be quantized or made particle-like, in order to exist in physical reality. This is a reminder that matter, energy, space, and time, must coexist for reality to be as it is. We need all four observable quantities to be present at once, for physical reality as we know it to exist at all. And yet it is clear they can be unified. As I said earlier, there is a hierarchy to these quantities, and I believe that the most essential – or most fundamental – quantity is time. Without time, there would not be even the possibility for other properties to arise, in my view. The zero-brane is normally viewed as existing in, or defining, a 1+1 dimensional embedded space. This is because even if it is effectively a point particle, having no spatial extent, it must have at least an infinitesmal aspect in time to exist at all! Thus it is sometimes referred to as an instanton, or a non-minimal point particle. Once there is a moment for events to happen in, or successive moments in which processes can unfold, the next thing we need is an arena where such processes can happen, and that is space. Once we have both time and space, we need energy to drive processes – initiating action or providing an action potential. Then, of course; having matter gives the energy something to act upon or to become the product of actions and processes.

Conclusions:

When considering what is ultimately possible in Physics, we must remind ourselves again and again that Physics is the study of observable quantities and phenomena. If we get too far from what we can observe and measure, we are not doing Physics. We are looking to engender an understanding of reality, however, rather than merely to create a catalog of what is real. So Physics necessarily requires us to formulate models of reality, and to test their predictions by comparing what is observed with what our models suggest should happen. To proceed without models of any kind would make our progress almost impossible, though we might build up an impressive knowledge nonetheless. Seng T'san suggested "Stop talking, stop thinking, and there is nothing you will not understand" but scientists need to think, and to think well about reality, for Science to progress. We could learn something, though, from the old Chinese philosopher – as by being too full of our own thoughts we can crowd out any insights or clear observations about reality.

We need to guard against what is known as the Einstellung effect, which is the tendency to reject new models of reality – if the old models have worked well in the past – no matter how much better the new model might be. So even if a new model offers a much clearer picture, more predictive capability, and all sorts of other advantages which aid our understanding or the utility of our modeling, people tend to fall back on their old world-view even if trying to brave new ground. I have seen that people in all disciplines, including great scientists, will cling to well-worn concepts and theories, even though there is clear evidence of their limitations. This is why people in Biology and Physiology point to more than 200 years of progress through reductionism and look forward to 100 more, even while Physics has accumulated evidence for more than 100 years that reductionism is plainly wrong. So there is a disconnect here. This is an especially relevant issue, as it is becoming more and more necessary to always work from the most recent data, or the most up-to-date interpretations thereof. Instead of trying to simply flow with the prevailing belief system, however, we really need to learn to think for ourselves. Sometimes the prevailing beliefs are wrong.

After having seen clear demonstrations that entropy is not disorder, but rather the spreading and sharing of energy, or its dispersal, I became acutely aware of how entrenched the old concept was. In this age of discovery, however, Science moves forward very quickly. I find myself re-working some papers again and again, and wishing I'd done yet another revision, because try as I might it is not possible for me to keep up with all the latest information that is germane to my topic. I do not want to be the victim of old models that no longer serve to advance Science, as that might stifle the potential for further progress. I would rather have no model at all, or to entertain many models, than have a fixed view of reality which does not serve to foster understanding. My fondest notion is that the sum total of all possible models is actually the best model, the ultimate Master Equation, or the road to Ultimate Unification. Philip Gibbs referred to something called the "Theory of theories" in his book Event-Symmetric Space-Time, and I have found great utility in this concept. Briefly stated; this idea is that reality is a sort of path integral, and natural law a weighted average, based on all possible mathematical theories and ideas about reality that make sense out of it.

In such a notion; a liberation can be found which is sufficient to let the growth of understanding in Physics continue almost indefinitely. But only by suspending judgment, and disallowing the premature formation of conclusions, can we continue to make progress. If there are broad areas of theory, forces, or particles which remain as yet undiscovered, they will influence us every bit as much now as when that discovery occurs. It is not as though our ignorance of new principles protects us from the forces generated by them. If we believe, as they did at the end of the 19$^{th}$ century, that most of the essential laws and principles of Physics have been discovered, we will be in for big surprises! But if we can remain open minded, there is much progress to be made and many exciting discoveries await us. And we are the ones who can make those advances. There is a whole universe of knowledge waiting to be discovered, perhaps even more than that. If you believe some theorists, there could be not one but many universes for us to discover and explore.

Laura Mersini-Houghton set forth a theory as a possible solution to the 'landscape problem' in String Theory, which is conceptually very much like Phil Gibbs 'theory of theories' idea and is based on natural selection. This problem arises in String Theory, because of the great multiplicity of alternate universes possible, when attempting to find a singular solution which resembles our universe. Theorists ask "How is such a possibility selected?" The landscape of unique solutions is so deep and broad that any number of possible universes could be created, and scientists wonder why we just happened to end up with a universe like ours, that can support living creatures such as ourselves. Mersini-Houghton proposes that it was natural selection, with Wheeler-DeWitt serving as a Master Equation for a whole system of universes, and the choice being rendered by the non-local interactions among the various branches of the possibility tree. That is; if there are indeed many universes, or different branches of the timeline, just as Everett imagined, the non-local connections arising from the entanglement between particles would remain intact, even when some ended up in one branch or universe, and some in another. So perhaps we are here because they 'landed' there.

Now; this seems pretty far-fetched, even to an open minded fellow like me. But she offers empirical evidence, and a means by which future evidence might either verify or invalidate her theory. To share the means of disproof demonstrates willingness to take a risk for the advancement of Science. But in addition to courage, one needs a belief that your 'crazy' idea may turn out to be 'right.' Of course; that means that it too will likely be superseded some day, just as Newton's formulas got superseded by Einstein's. Perhaps Einstein's version of Relativity will be seen as a special case of Nottale's expanded framework of relativity one day. Or maybe Minkowski was right, where Einstein got it wrong, and Alex Mayer's version will be found closer to the truth. But a lot of other people have realistic answers which should be examined, or deserve attention. David Roscoe (whom I also met at CCC-2) makes a convincing case that electrostatic potential – commonly viewed as a scalar quantity – should actually be seen as a tensor, especially in cosmology. It remains to be seen whether the expanded framework Roscoe offers thereby increases our understanding – giving us a better grasp of things by revealing electrodynamics' hidden structure – or is simply a lovely trip to the mountains.

What *is* obvious to me is that we still have a lot to learn. Certain knowledge is impossible to unlock until one has the tools, and the Math used in physical theory continues to evolve. Plus we have learned so much from observations of the cosmos in the past 20 years that all our textbooks needed to be re-written. So I believe that what is ultimately possible to learn in Physics is far more than we know now and perhaps more than we could possibly have learned by this point. But we must keep looking forward, looking for new answers where they are, rather than seeking where the answers were because that was fruitful in the past. Even if there are definite limits to our knowledge, the progression of learning is still virtually endless or boundless. The realm of what is known continues to progress into the realm of what is unknown but knowable. And things we thought were unknowable, because of fundamental limits, are found - in some cases - to be knowable after all! I am inclined, therefore, to assert that humans will continually become more and more understanding over time. However; it is also possible that we will become wiser. And perhaps wisdom is actually what we want to have, as scientists, rather than knowledge or understanding. Perhaps what is ultimately possible in Physics is that we will become wise about what we know and understand. And that may be the most exciting possibility of all!

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