The Myth of a Theory of Everything

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Abstract

A fundamental assumption embedded in our current worldview is that there exists an as yet undiscovered 'theory of everything', a final unified framework according to which all interactions in nature are but different manifestations of the same underlying thing. This paper argues that this assumption is wrong because our current distinct fundamental theories of nature already have mutually exclusive domains of validity, though under our current worldview this is far from obvious. As a concrete example, it is shown that if the concepts of mass in general relativity and quantum theory are distinct in a specific way, their domains become non-overlapping. The key to recognizing the boundaries of the domains of validity of our fundamental theories is an aspect of the frame of reference of an observer which has not yet been appreciated in mainstream physics. This aspect, called the *dimensional frame of reference (DFR)*, depends on the number of length dimensions that constitute an observer frame. Edwin Abbott's *Flatland* is used as point of departure from which to provide a gentle introduction to the applications of this idea. Finally, a *metatheory of nature* is proposed to encompass the collection of theories of nature with mutually exclusive domains of validity.

Keywords: Theory of Everything, Domain of Validity, Actual Mass, Actualizable Mass, Dimensional Frame of Reference, Metatheory of Nature

To Mom and Dad

1 Introduction and a Brief History of the Rise of Unificationism in Physics

A fundamental assumption that underlies much of contemporary research in foundational physics is the idea that there exists a final, unified theory of nature according to which all interactions which manifest themselves to us as distinct are in reality different aspects of the same underlying thing. Such a theory has been dubbed a 'theory of everything', although this designation is a bit of a misnomer. It is usually meant to refer to a theory of the fundamental principles that govern all of our laws of physics, and in particular one which unifies quantum theory with general relativity. It is understood that certain aspects of nature, in particular emergent phenomena, may not be explainable using such a theory in any practical manner, and that therefore the designation only applies in a restricted sense[1].

This paper argues that there is no such unified theory of nature, even in the more restricted sense. It will attempt to show that, rather, we have reached a point in our understanding of nature at which we have to describe her in terms of a collection of theories with mutually exclusive domains of validity. The collection of such theories cannot be considered *a* theory of nature, but must be considered part of a *metatheory of nature*. How the metatheory of nature is different from our current conception of a theory of everything will become clear in the course of this paper.

Our current ideas on this matter are strongly motivated by historical reasons, and to gain a better appreciation for this it is useful to review the history of unification in physics briefly. It does not appear that

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the notion of a explaining different interactions as different manifestations of the same thing was rooted in antiquity. For instance, in Aristotelian physics, celestial bodies underwent eternal circular motion whereas terrestrial objects would move ideally in straight lines toward their 'natural place'[2].

The first major unification of seemingly distinct physical phenomena occurred in the 17th century, when Newton, by applying his three laws and his universal law of gravitation, demonstrated that the gravitational motion of earthly bodies could be explained by means of the same force that governed the gravitational motion of celestial bodies. He published his results in 1687 in the well-known *PhilosophiæNaturalis Principia Mathematica* (Mathematical Principles of Natural Philosophy)[3].

Other phenomena, however, still remained apparently disconnected: Certain objects, after being rubbed were observed to attract other ones, a phenomenon called electricity, while other objects like lodestone exerted an effect at distance on other objects, something which was called Magnetism. Over the course of the 19th century, due to the observations and work of Ampere, Faraday, Oersted, Weber and many others, it became increasingly clear that electricity and magnetism were closely related to each other. In 1873 Maxwell demonstrated in his *Treatise on Electricity and Magnetism* conclusively that the two phenomena were but two aspects of the same thing. The equations that express their respective fields in terms of each other now bear his name. Some simple mathematical manipulation of these equations revealed that electromagnetic waves could propagate in space at the speed of light. This led to the conclusion that light was an electromagnetic wave. Hence, optics, which was up until then considered a completely separate field, was also unified with electromagnetic theory[4].

The 20th century saw two major revolutions in our fundamental understanding of nature: Relativity and Quantum Mechanics. The former was, as is well known, developed by Einstein in 1905 and generalized Newton's three laws to regimes in which relative velocities were extremely high, and as such became known as the *special theory of relativity (SR)*. The latter, developed by many well-known physicists over the period 1900-1926 (counting the time from the discovery of Planck's constant to the full formulation of the mathematical formalism), replaced Newtonian Mechanics in the limit of extremely small scales. The two theories were developed independently and indeed seemed not to have much to do with each other. For instance, the central equation of quantum mechanics, the Schrödinger equation, is manifestly non-relativistic because it treats time and space differently, whereas according to SR they should be treated on an equal footing. However, efforts to combine them in such a way that the resultant theory could accurately describe extremely small objects relativistically were soon underway. Already in 1927, Dirac discovered the relativistic generalization of the Schrödinger equation, and by the late 1940's Schwinger, Tomonaga and Feynman each discovered independently comprehensive frameworks combining relativity and quantum mechanics. Dyson then showed that their formulations were mathematically equivalent and subsequently, it came to be known as *quantum electrodynamics (QED)*[5].

There were, however, other challenges: For one thing, two new fundamental types of interactions were discovered, the weak and the strong force, which did not appear to be describable through the framework of QED. The other problem was that gravity did not fit the pattern of the other quantum theories. Ten years after formulating his special theory of relativity, Einstein was able to generalize it to a theory of gravity, which he called the *general theory of relativity (GR)*. In GR, the gravitational force is re-conceptualized as a manifestation of the curvature in the very structure of spacetime itself. This conception is altogether foreign to the quantum theories, in which forces are conceptualized in terms of so-called force exchange particles. For the electromagnetic force, these are the photons, for the weak force, the Z and W bosons, and for the strong force, the gluons. Einstein spent the last 30 years of his life seeking a 'unified field theory' combining gravity with electromagnetism, but was unsuccessful. It is generally thought that his effort was doomed from the start because the strong and weak interactions were only discovered around the time he died.

The last major unification in physics occurred when by 1968 Weinberg and Salam, based on prior work by Glashow, independently showed that the electromagnetic and weak interactions could be expressed as different manifestations of a single *electroweak force*[6].

In light of these successful unifications, it is eminently reasonable to assume that this program can be carried further. Current efforts attempt to unify the strong force with the electroweak force to create what is called a 'grand unified theory' (GUT), while other efforts attempt to unify quantum theory with general relativity through a quantum theory of gravity. A framework that unifies a GUT with gravity is called a 'theory of everything'.

2 Domains of Validity

An important implication of the idea of a 'theory of everything' is that its domain of validity must encompass all interactions of nature. For instance, it appeared that electricity and magnetism, being concerned with different physical situations, had mutually exclusive domains of validity. Maxwell's equations showed that this was not the case, and this became especially evident when through an understanding of relativity and its associated spacetime symmetries one could conceive of magnetic fields in a sense as a relativistic manifestation of electric fields. The process of unification then involves a merging of the domains of theories which had been up until then considered to be mutually exclusive. The implication of our current worldview therefore is that the phenomena of gravity and the forces described by quantum theory have, at a sufficiently fundamental level, a common domain of validity. To be sure, it has been considered that this may not be the case, but this is not a widely held view. For example, Wald [7, pp.382-383] gives the following argument to demonstrate that this view is "untenable, because the spacetime metric is coupled to matter sources":

> Suppose spacetime structure is described by a classical spacetime (M, g_{ab}) and quantum theory applies to the matter source. What is the curvature of spacetime associated with a given quantum state of the matter? If the classical Einstein Equation is to hold in the limit where the matter distribution can be described classically, the most natural candidate for a quantum version of Einstein's equation (with gravity treated classically), is
>
> $$G_{ab} = 8\pi < \hat{T}_{ab} > \tag{1}$$
>
> Where $< \hat{T}_{ab} >$ denotes the expectation value of the stress energy operator $\hat{T}_{ab}$ in the given quantum state. Now consider a state of matter where, with probability 1/2 that all the matter is located in a certain region, O_1, of spacetime and with probability 1/2 the matter is located in a region O_2 disjoint from O_1. According to equation [1], the gravitational field will behave like half of the matter is in O_1 and the other half is in O_2. Suppose, now, that we make a measurement of the location of the matter. We then will find the matter to be either entirely in O_1 or entirely in O_2. If equation [1] continues to hold after we have resolved the quantum state of the matter by this measurement, then the gravitational field must change in a discontinuous, acausal manner. Thus the attempt to treat gravity classically leads to serious difficulties.

Wald's formulation of the challenge of how to understand the relation between general relativity and quantum theory illustrates especially nicely how the fundamental problem is *not* that these theories seem to give mutually incompatible descriptions of nature, but rather *that they are assumed to have shared domains of validity.* The equal sign in equation (1) dictates that one to must find a way, by hook or by crook, to render two mutually inconsistent descriptions of nature consistent with each other. That is why most people who try to solve this problem attempt to do so by trying to formulate a quantum theory of gravity, despite the fact that there is not a single shred of experimental evidence to suggest that gravity needs to be described by a quantum theory by us.

As is often the case with a physics argument about a deep aspect of nature, it is only as strong as its most fundamental assumptions. A central assumption of Wald's argument is that the concepts of mass in general relativity and in quantum mechanics are the same. This is such an obvious assumption that it appears ridiculous to question it, but is precisely the one that needs to be challenged in order to recognize that general relativity and quantum theory may actually have mutually exclusive domains of validity.

It might seem surprising, but we do *not* actually have direct empirical evidence that the conception of mass is exactly the same in general relativity and in quantum theory, or, put more succinctly, that the physical quantity denoted by the symbol m in GR is identically the same quantity as that denoted by m in quantum theory (prior to a 'measurement'). What would constitute this kind of evidence would be the measurement of the superposed gravity field of a massive object as it exists in a quantum superposition, but unfortunately gravity is far too weak and the masses of objects observable in a quantum superposition are far too small in order for such an experiment to be carried out realistically in the near future.

A couple of objections might be leveled against the claim of lack of evidence: First, it would seem internally inconsistent if quantum objects, which typically are constituents of larger objects associated with the general relativistic conception of mass, were not themselves associated with it. However, this objection is only valid if gravity is not an emergent phenomenon: To provide an analogy, no one would object to the fact that a single particle is not associated with the concept of temperature, even though it is the constituent of larger objects which definitely are. In the characterization of the difference in the concepts of mass between the two theories that follows, gravity will be shown to be an emergent phenomenon, and hence this objection may not be applicable. Second, experiments such as that performed by Staudenmann *et. al.*[9] have confirmed

that neutrons even in a superposition are passive gravitational charges affected by the Earth's gravitational field. But these tests and other phenomena, such as the gravitational bending of light, may be no more than an indication that the spacetime manifestations of these objects (i.e. their path integrals) conform to the background geometry of spacetime. To empirically demonstrate that general relativity does in fact have a shared domain of validity with quantum theory, one must measure the gravity field of an object as it exists in a quantum superposition. If one were to detect a superposition of gravity fields, then this would be incontrovertible evidence that the theories do in fact have shared domains of validity, and, indeed, that gravity must be more fundamentally described by a quantum theory. To date, *such evidence does not exist.*
In previous work [10], this author explored the possibility that the concepts of mass in the two theories are distinct in a very specific way. A more complete discussion of this distinction and its implications is provided in that reference, but here it will only be summarized as follows: to give a label to the distinction, mass in General Relativity will be called *actual*, and mass in quantum theory prior to a 'measurement' will be called *actualizable*. Actual mass never exists in a superposition of properties but always produces gravity fields whereas actualizable mass is always in a superposition of properties but never produces gravity fields. This distinction sharply segregates the domains of validity of GR and the quantum theories, which are bridged by means of what we currently in quantum theory call a 'measurement'. Less anthropocentrically, according to this distinction, the reduction of the wave function of a quantum system can be thought of as a consequence of the *actualization* of the system's massive constituents, which moves it from the domain of quantum theory to that of general relativity. In short, a 'measurement' is tantamount to the creation of a gravitational field.

3 The Concept of Dimensional Frame of Reference

The obvious question now becomes, what could be the physical reason for such a distinction? To answer this, let us turn to one of the best known novellas in the history of science fiction, *Flatland*, by Edwin Abbott[8]. In it, A Square, a resident of flatland, a two-dimensional world, is visited by a sphere who tries to explain to him the differences in how they observe things. The story does not give a label to what is responsible for these differences, but for convenience sake one can define it: Let the *dimensional frame of reference (DFR)* be that aspect of an observer's frame which is due to the number of its constituent length dimensions. A square, then, being only able to observe things in two spatial dimensions, has a 2-DFR whereas the sphere has a 3-DFR (as do we).
From reading the novella, one might come away with the impression that an observer with a 3-DFR would observe a truly 2-dimensional object as 2-dimensional. This is not entirely correct. If it is the case that the plane in which the two-dimensional object exists is associated with a third coordinate in the higher-dimensional embedding space, then it would indeed appear 2-dimensional. But if the plane is not *a priori* associated with a third coordinate in that space, then this reasonable assumption is demonstrably false. To see this, consider a two-dimensional object like a square in Euclidean 2-space, as in figure 1.

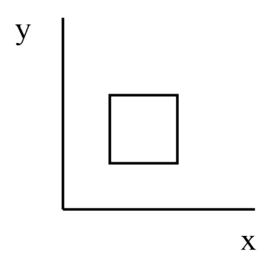

Figure 1: **A square in Euclidean 2-space**

If we wish to describe it as observed by an observer with a 3-DFR such that the x and y coordinates are kept, and the plane is not associated with a z-coordinate in 3-space, then the square manifests itself in Euclidean 3-space as an *infinitely long square column*, as depicted in figure 2.

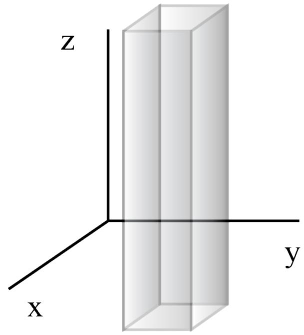

Figure 2: **The square as described by an observer with a 3-DFR**

Notice that the column is *not* an actual object, the actual object is just a square. Rather, the column is an artifact created by the mismatch between the dimensionality of the observed object and the DFR of the observer. It is created by the fact that the Euclidean plane was not assigned a z-coordinate and hence the representation of the square in 3-space requires the inclusion of all z-coordinates.
Let us suppose that an observer with a 3-DFR could attribute to the square an interval along the z-axis, say, equal to the lengths of its sides. In that case, the infinitely long column would “collapse” to a cube where the interval along the z-axis was attributed, as depicted in figure 3.

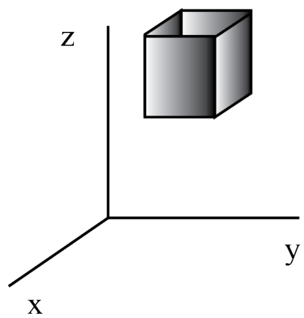

Figure 3: **The column has “collapsed” to a cube upon attribution of an interval along the z-axis**

This cube is now an actual object in 3-space, unlike the column, which can be conceptualized more suggestively as a *superposition of an infinite number of cubes* along z-axis, as in Fig. 4

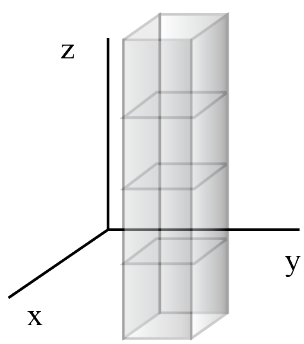

Figure 4: **The column as a “superposition” of an infinite number of cubes**

The cubes are depicted next to another without overlap but a more accurate picture would show a stack of cubes overlapping at each infinitesimal displacement along the z-axis. Because the resultant picture, rather looking like a stack of extremely flat cuboids, would not convey this idea, it is not drawn that way.

The reader is invited to take a step back for a moment and contemplate just how unexpected and remarkable it is that a single two-dimensional object could manifest itself to an observer with a 3-DFR as a *superposition of three-dimensional objects*. We can even contrive to make this reminiscent of the situation described in Wald's argument: Let us suppose that we could suppress the manifestation of the square everywhere in space except for two regions, which we label as O_1 and O_2, as in figure 5.

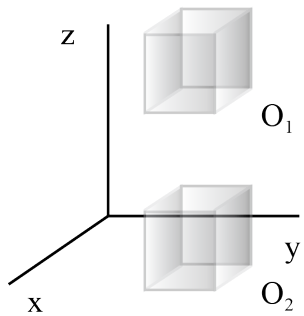

Figure 5: **A Euclidean Analogy to Wald's scenario**

It looks like there are two objects in 3-space, but in reality there is only one object in 2-space. Again, the cubes forming this superposition are not actual objects. Yet, they are also not the same as "nothing" because the regions they occupy are distinct from surrounding regions in that only where they are does the possibility exist for an actual cube to emerge out of the square upon the attribution of a z-interval. Only where they are can a cube as an object in 3-space *actualize*. It is therefore apt to label these cubes, and the infinitely long cubical column from before, as *actualizable*, and the single cube into which they "collapse" as *actual*. Comparing this terminology with the previous distinction between the concepts of mass in GR and in quantum theory provides the clue needed to understand the physical reason for the distinction. Actualizability refers to an *intermediate state of existence*: an actualizable object is not quite something that exists, but it is not something that does not exist, either. This clashes with another one of our deeply held assumptions, according to which things can either exist or not exist, but not anything in between.

We have so far only dealt in analogies because it is hoped they will provide a gentle introduction to ideas that are radically different from what is currently mainstream, and which are therefore necessarily going to be highly unfamiliar. By contemplating these analogies, one can develop an intuition for a framework which provides a mathematical explanation for how to 'understand' what quantum mechanics tells us about reality and how it fits with general relativity based on these realizations. Such a framework has been developed by this author and is called the *Dimensional Theory (DT)*.

Briefly, the theory assumes that there exists a limit in which spacetime reduces to a 2+1 analog called *areatime*, and that quantum phenomena arise when spacetime observers attempt to describe the spacetime manifestations of objects in areatime which have not yet emerged as actual systems in spacetime. The actual objects in spacetime are *worldlines*, and since areatime objects do not have spacetime worldlines (they must have areatime worldlines, of course), they have to be described by observers with a 3-DFR, i.e. spacetime observers, in terms of a *superposition of all possible worldlines* of the massive objects into which they can emerge. The worldlines forming this superposition are therefore not actual spacetime objects, and their associated particles along with their masses are not actual but actualizable. A symmetry is postulated which allows for an indirect comparison of the passage of time along the areatime object's actual worldline in areatime and each actualizable spacetime worldline that is part of the superposition. A simple mathematical transformation turns this symmetry into two complex conjugate phase factors of the form $e^{\frac{\tau}{\tau_A}}$, where τ is the proper time associated with a particular actualizable worldline and τ_A is the proper time of the areatime object, which due to the symmetry manifests itself to spacetime observers as an *imaginary period.* Upon appropriate substitution for τ_A the phase factors become $e^{\pm i\frac{S}{\hbar}}$, where S is the action of the spacetime manifestation and $\hbar$ is Planck's reduced constant (This was the subject of the author's entry to the third FQXi essay contest [11]). Reframing each actualizable worldline in terms of a path in space traversed over an interval in time requires associating the paths with the phase factors because the passage of time in spacetime as the path is traversed must be compared against the passage of time for the object in areatime (since the path is not an actual path in space, but just a manifestation of the areatime object's worldline). Summing over all possible paths gives the Feynman path integral, with which one can derive the quantum state Ψ of a system from an earlier state Ψ_0. Since the state is derived using actualizable worldlines, paths and particles, it is also actualizable. If the limit in which spacetime vanishes is exceeded, the mass associated with the superposition actualizes and all the possible actualizable spacetime manifestations of the areatime object "collapse" to a single *actual* spacetime object with a single actual spacetime worldline. This corresponds to what in canonical quantum mechanics is called the "state vector reduction": The superposition of actualizable states $|\Psi>$ collapses to a single actual state $|\underline{\psi}>$, which is underlined to indicate its ontological distinction. Space constraints make this summary necessarily perfunctory, but a recorded conference talk more effectively summarizes this framework and provides a link to all of this author's previous works on the DT[12]. Let us now return to Wald's argument. If the dimensional theory is correct, then, instead of equation (1), we have

$$G_{ab} = 0 \tag{2}$$

prior to the measurement, because there is not yet any spacetime object that could couple to the spacetime metric, only something in areatime which manifests itself to spacetime observers as a superposition of two actualizable matter distributions describable by the expectation value $< \hat{T}_{ab} >$. Upon measurement, the Einstein equation turns into $G_{ab} = 8\pi \underline{T_{ab}}$ with probability 1/2 that the actual (hence underlined) matter density will be found in O_1 and with probability 1/2 that it will be found in O_2. Thus, if mass in quantum theory describes a different concept than in general relativity in the specific manner explained above, then the attempt to treat gravity classically does not lead to any difficulties.

Note also how this explanation automatically accounts for the appearance of non-locality in quantum mechanics: if one measures the matter density at, say, O_1, one instantly knows that it is not to be found at O_2 no matter how far apart the regions are. This would *seem* to indicate that nature is non-local, but it doesn't: The superposition of matter densities is not a superposition of actual spacetime objects, it is just the manifestation in spacetime of the same single underlying areatime object. The detection of the matter density at O_1 (which is a spacetime event) and the vanishing of the probability amplitude for the matter density to be at O_2 (which is *not* a spacetime event), though possibly very far apart in space, involve the same region in areatime. The mathematical reason for this is that the phase factor of the wave function, ultimately coming from the $e^{\frac{\tau}{\tau_A}}$ term, incorporates the areatime proper time, which is to say, the *areatime metric interval* associated with the areatime object. Similarly, if two or more objects are described by the same non-factorizable wave function, then they are manifestations of something in just a single region of areatime, because they share common phase factors. Thus, to be described to by the same wavefunction *is* to be in the same areatime region. Had this theory been discovered prior to Aspect's experiments [13] (which it could have, since it involves no new information that wasn't already known by the 1940's), it could have used the prediction of entanglement in quantum mechanics to argue that, if experimentally confirmed, it would be direct evidence that spacetime emerges out of areatime. Alas, now it is merely a postdiction.

The concept of a DFR is conspicuously absent in contemporary theories of physics, which implicitly means we assume our current conception of an observer frame of reference is complete. By now it should be evident that quantum superposition can make a lot more sense if we discard this assumption and incorporate the concept of DFR into our understanding of nature. Incorporating it leads to an explanation for the distinction between actual and actualizable mass, which in turn sharply segregates the domains of validity of quantum theory and general relativity. If the domains of validity of general relativity and quantum theory are in fact sharply separated, then there cannot exist a 'theory of everything' as understood today.

4 A Metatheory of Nature

If there is no such thing as a theory of everything according to which all interactions can be explained as different manifestations of the same underlying thing, then what is there? We can find an answer by realizing that the basic ideas just presented can be straightforwardly extended to different numbers of dimensions. For example, a quantized description of gravity suggests itself by increasing the number of dimensions by one: In exact analogy to the relation between areatime objects and spacetime observers, one can posit that there exists a limit above which a one-dimension higher analog of spacetime comes into existence. Spacetime objects would manifest themselves to hypothetical observers in this 4+1 analog in a superposition of all the possible higher-dimensional objects into which they could emerge once the higher-dimensional analog of a 'quantum measurement' occurs, and their gravitational interactions would likely be described in terms of a quantum theory. Note how this provides a possible explanation for why we, who are unable to observe events in 4+1 dimensions, have never empirically observed quantum gravitational phenomena in nature.

So, this novel conceptualization of the relation between our most fundamental theories of nature involves a profound shift in our underlying worldview from one in which there is thought to exist a unified theory of everything to one in which there exists a *metatheory of nature*. This 'theory of theories' specifies the individual theories (or sets of theories) that apply to a particular combination of the dimensionality of the objects under consideration and the DFR of the observer, as shown in Fig. 6 in the Appendix.

The association of dimensionality with size arises from the fact that higher powers of length change faster with a change in scale than lower powers. This turns any length scale also into a "relative dimensionality scale". For instance, of two 3-D objects of same shape but different size, the smaller one has more units of area per unit of volume than the larger one, which can be interpreted as the smaller object being more 2-dimensional than the larger one or the larger one being more 3-dimensional than the smaller one. Presumably, in certain limits, differences in relative dimensionality turn into differences in absolute dimensionality which form the maximal boundaries of the domains of validity of individual theories of nature. In the case of the postulated limit in which spacetime reduces to areatime, the close association of mass with the emergence of spacetime causes the limit to manifest itself as a dynamic rather than geometric quantity, namely the *action*.

Fig. 6 may be slightly reminiscent of the periodic table of elements, and indeed there is an interesting analogy. Prior to its discovery by Mendeleev, it was not realized that the known elements could be classified according to certain regularities in their properties. Similarly, our fundamental theories of nature, though distinct, may display certain patterns that reoccur with changes in dimensionality. For instance, the classical theories of both gravity and electromagnetism obey an inverse square law, and it is not unreasonable to think that, say, a classical theory in 4+1 dimensions should obey an inverse cube law. Similarly, the quantum theories that form the standard model share common features like quantum superposition and gauge invariance which may well be features of different-dimensional quantum theories. Thus one has potentially a way of systematically looking for patterns to better understand *why* our fundamental theories of nature are just the way they are.

The rationale for placing our known theories of nature according to the schema given in figure 6 is as follows, where we will use (Dimensionality of observed event, DFR of observer) to refer to individual boxes: The dimensional theory already suggests that quantum mechanics belongs to the (2,3) box. One can consider quantum electrodynamics as a relativistic generalization of quantum mechanics, and since it has been unified with the weak force both of these also belong to the (2,3) box. The idea that the strong force belongs into the (1,3) box is a guess based on its more complicated gauge symmetry, its very short distance scale and its unique feature of asymptotic freedom. The classical theories naturally go into the (3,3) box, with the justification for putting Maxwell's theory there being that its charges are never in a quantum superposition. In that sense, one might think of its domain as that which encompasses electricity and magnetism after objects have emerged in spacetime. Because of the correlation between size and dimensionality, one might expect at very large scales relative to us a 4+1 dimensional analog of spacetime to emerge, and if any events or objects above that limit produce manifestations observable to us, these would likely be unexpected phenomena. Dark matter and dark energy are unexpected phenomena observable to us only at very large scales, hence it is guessed that the underlying theory or theories describing these belong to the (4,3) box. A quantum theory of gravity, on the other hand, would go into the (3,4) box for the reasons mentioned above.

Finally, it is particularly striking how little it suggests we actually know about nature, and how narrow our current conception of a 'theory of everything' seems in its light. Our current ideas about nature only involve a small fraction of the metatheory's domain, most of which is not even in principle observationally accessible to us. The best we might be able to do to better understand, say, how observers with different DFR's perceive the world would be to create computer simulations. Thus, the metatheory transcends what one might think of as a 'theory of nature'; the quantitative description of major parts of it can at best be considered *mathematical metaphysics*. But perhaps this is the beauty of approaching an understanding of nature at the deepest level: the objective distinctions between physics and metaphysics (and possibly even mathematics) simply vanish as they have now become dependent on the frame of the observer. For example, to an observer with a 4-DFR, Newtonian mechanics is *not* physics but mathematical metaphysics. In this very different sense, the metatheory could even be argued to be *more* unified than our current conception of a theory of everything.

5 Conclusion and a Brief History of the Fall of Anthropocentrism in Physics

This paper has argued that a very basic part of our worldview, that all the forces of nature are expected to be unifiable in one framework, usually called a 'theory of everything', that explains them as different manifestations of one underlying thing, is incorrect. When an assumption is deeply embedded in a particular worldview, then challenging it necessarily involves challenging other deeply held assumptions because no truly fundamental assumption about nature exists in isolation: other concepts, ideas and assumptions depend and build on it, so that discarding one necessitates discarding a host of others. In the course of presenting the argument in this paper some of the other fundamental assumptions that needed to be discarded were: the notion that the concepts of mass in general relativity and in quantum theory are the same; that lower-dimensional objects should necessarily appear lower-dimensional to us; that an object can either exist or not exit and nothing in between; that our current concept of an observer frame of reference is complete; that spacetime encompasses all of nature; and that there exists an objective boundary between physics and metaphysics. It should not be unexpected that some of these have not been previously recognized and identified as assumptions because it is often those too subtle to detect that cause conceptual obstacles to deeper understanding.

We began with a brief history of unification in physics and will now end with a brief history of how physics led to the realization of man's insignificance in nature. The point of this is to demonstrate that a conceptual development that dramatically breaks with one major historical trend in science can at the same time be the culmination of another.

In Aristotelian physics the earth, man's home, was the center of the universe. A major part of the reason that the theory persisted for over 2000 years into the 16th century was because this highly anthropocentric view of the universe fit prevailing religious dogma extremely well. There were known problems with the geocentric worldview, such as the 'retrograde motion' of the planet Mars, but this was explained by Ptolemy in terms of epicycles, smaller circular paths along which an object in orbit travels. However, other oddities, such as why the retrograde motion occurred only when Mars was in opposition to the Sun remained unexplained. Also, increasingly accurate observations required the introduction of additional epicycles, making the theory increasingly cumbersome and ugly [2]

In 1543, Copernicus proposed in his work *De revolutionibus orbium cœlestum* (On the Revolutions of the Celestial Spheres) a radically different interpretation of the observed astronomical phenomena, namely, that the earth and the other planets revolved around the sun. His idea set the stage for a dramatic expansion of man's concept of nature, and the major shift in worldview it brought about was later recognized as so significant that the notion that 'we are not special' came to be named the *Copernican principle* [14].

It is possible that for a time people might have thought that our sun is special, but as our ability to peer into space improved, we came to realize that it is only an average star among billions of others in our galaxy, the Milky Way. The notion that our Milky Way might be special hung around for somewhat longer. The famous debate between the astronomers Shapley and Curtis in 1920 about whether it was unique or not indicates that fewer than a hundred years ago this question was still not settled. Subsequent observations by Hubble confirmed that what had been considered 'spiral nebulae' were in fact other galaxies like our own. Accumulating evidence thereafter solidified the fact that our Milky Way is only an average galaxy in an average galactic cluster[15].

The decline in the anthropocentric worldview has come so far that when in 1998 it was discovered that most galaxies are receding from us at an accelerating pace, this was interpreted without appreciable discussion as a phenomenon that could be observed anywhere in the universe[16][17].

Nonetheless, a vestige of anthropocentrism remains in the assumption that the repository of our existence, spacetime, is special. The assumption is implicit but definite, given by the fact that our established fundamental theories of nature make no explicit reference to other repositories of existence. What the metatheory suggests is that spacetime is no more special than our planet Earth turned out to be. Both make us seem special because that is where we happen to exist. Since the number of dimensions is arguably the most fundamental physical parameter that characterizes our existence, the metatheory consummates the Copernican Principle: we inhabit not only an unremarkable speck in space, but a space the dimensionality of which itself is unremarkable. What hubris to think that the description of nature in all its richness would be exhausted just by unifying a few types of interactions in our small corner and calling this a 'theory of everything'.

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Appendix: A Schema of the Metatheory of Nature

Size ⟶	Dimensionality of observed event	4	?	?	Dark Energy (?) Dark Matter (?)	?
		3	?	?	General Relativity Classical Mechanics Classical E&M	Quantum Gravity
		2	?	?	Quantum Mechanics QED Electroweak Interactions	?
		1	?	?	Quantum Chromodynamics (?)	?
		0	1	2	3	4
		Dimensional Frame of Reference of observer				
		Size ⟶				

Figure 6: **A metatheory of nature.** *The numbers on the vertical axis refer to the length dimensions that characterize the dimensionality of the observed event or object, and the ones on the horizontal axis refer to length dimensions that characterize the dimensional frame of reference (DFR) of the observer. Each box circumscribes the maximal boundary of the domain of validity of a particular theory of nature. The maximal boundary can be thought of as the 'outermost possible limit' of the domain of a theory of nature. For instance, gravity has a larger domain of validity than classical electromagnetism because all electrical charges have mass, but not all masses have electrical charge. Thus the actual domain of classical electromagnetism is smaller than that given by its maximal boundary. It would be equal to it in a universe in which every mass has electrical charge. The ascending diagonal boxes describe classical theories of nature because the dimensionality of the observed event matches the DFR of the observer. The boxes below the diagonal describe quantum theories because the dimensionality of the observed event is smaller than the DFR of the observer, and hence it must be represented by such observers in terms of the superposition of all possible actualizable manifestations of the objects into which it can emerge. The boxes above the diagonal are theories in which the dimensionality of the observed events exceeds the DFR of the observer, and the general mathematical features of such theories are at present unknown. Presumably if at very large (for example, galactic and above) scales a 4+1 dimensional analog of spacetime emerges, then the phenomena we call 'Dark matter' and 'Dark Energy' could be our observation of the spacetime manifestation of higher-dimensional events or objects. Conversely, the fact that we have not observed even a single quantum gravitational phenomenon empirically is because we are observers with the 'wrong' DFR: According to this framework, if we could make observations in 4 spatial dimensions, gravity would appear quantized to us. Our present worldview leads us to believe that our fundamental understanding of nature is nearly complete, and some seem to think that a theory of everything may be just around the corner. A cursory glance at this table reveals that this is not so. Furthermore, the fact that the table is limited to* 4×4 *length dimensions is not meant to suggest that nature itself does not continue on with this pattern at ever larger scales.*