Relationship between the wave function and space

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Abstract

We criticize the current standard interpretation of quantum mechanics, review its paradoxes with attention to non-locality, and conclude that a reconsideration of it must be made. We underline the incompatibility of the conceptions ascribed to space of field, and stage in modern theories, with differing roles for coordinates. We hence trace the non-locality difficulty to the identification of the basis space of the wave function and physical space. An interpretation of the wave function in which space loses its stage use at the local level, and its physical (field) meaning is assigned to the wave function, can solve this difficulty. An application of this proposal implies a field-equation extension based on a unified description of bosons and fermions able to provide new information on the standard model.
1 Introduction

Quantum mechanics (QM) is a successful theory describing phenomena in many ranges; it is also the standard framework for the study of elementary particles, when mixed with relativistic postulates through relativistic quantum mechanics and quantum field theory (QFT). QM’s ability of describing the constituents of nature lends support to its validity at a fundamental level. In general, QM faces no challenges on its capacity to describe nature in principle, except for the on-going and still open question of how to integrate it with general relativity (GR), and hence to include gravity in the description. Although the status of the theory remains solid in its applications at the operational level, paradoxes, confusion, and doubts linger on its conceptual basis, its interpretation, and even its consistency. In particular, these doubts have remained ever since the so-called Copenhagen interpretation imposed itself as the standard. Postulates of this interpretation continue to be questionable and cannot be satisfying for they lead to the renunciation of objectivity, determinism, and hence, ultimately to the impossibility of apprehending reality. At the center of this interpretation lies Bohr’s dictum that considers “the space-time coordination and the claim of causality, the union of which characterizes the classical theories, as complementary but exclusive features of the description...” Underlying these notions is Bohr’s stress that the nature of our perceptions forces all experience and links to experiment to be formulated in classical terms, which evokes the Kantian a priori categories. This interpretation also assumes the idea of an inherent property of nature which forbids assigning physical meaning to the variables describing the objects one is measuring (until they are measured).

One of the most poignant debates that followed this interpretation has centered precisely on this matter, namely, on whether the wave function carries the necessary information about an object, and in general, whether the quantum mechanical description can be considered complete. This question was raised by Einstein, Podol-
sky, and Rosen (EPR)\cite{2}, whose forceful negative answer was argued with a gedanken experiment in which they claimed a particle’s variables should be assigned before a measurement was performed, while QM forbids this assignment unless a measurement is carried out; this meant either an immediate transmission of correlations among particles through space, which was discarded as unphysical, or the conclusion that QM is not complete. Bohr considered sufficient the explanation that it is the experimental set-up which defines the measured physical quantities, and that this makes questions about the particles’ state before measurement meaningless. The EPR argument, on the other hand, implies the necessity of hidden variables that an alternative theory would support. Nevertheless, a later development of which both Bohr and EPR were unaware was a proof presented by Bell\cite{3} that the probability predictions of any local hidden variables theory should satisfy a series of inequalities which are violated by QM. Moreover, these inequalities can be subjected to experimental verification which was actually performed\cite{4}, with results in accordance with QM.

Thus, the EPR criticism has motivated an unexpected development in the sense that it has led to an additional confirmation of the validity of QM, but with the implication of the puzzling presence of “spooky” correlations in nature, that is, an inherent non-local behavior. In general, the Copenhagen positivistic interpretation cannot be satisfying because it renounces determinism and objectivity, which makes the EPR criticism understandable, but QM’s practical successes preclude yet the necessity of another theory.

In order to remedy this and other illnesses a variety of alternative interpretations have been constructed, but those based on the same questionable premises make questionable conclusions too. The interpretations range from assuming all the consequences of the Copenhagen interpretation of QM to assuming a purely classical view. At the first extreme, for example, the many-worlds interpretation of QM\cite{5} cures the discontinuity in the collapse of the wave function with the assumption that, upon
measurement, different states go to other worlds. However, by underlying the consistency, this interpretation sacrifices veridicality and seems more outlandish than the nature of the problems in the theory it intends to correct. At the other extreme lies Bohm’s\textsuperscript{6} which clings to old classical concepts. For the purpose of maintaining an ontological interpretation of the objects involved in the quantum mechanical description, it requires an unlikely understanding of terms as potentials with unphysical properties as being sourceless fields which violate the superposition principle. Although these interpretations can contain the usual quantum mechanical experiments in their framework, their use is less concise than the standard one’s, and they have not provided any new insight into physical problems.

It is our view that to renounce to scientifically questioning and debating phenomena beyond what is presently experimentally perceived cannot be sustained from the QM theory itself and is therefore unjustified; indeed, the closed and self-contained nature of the Copenhagen interpretation has prevented a discussion on what should be a central theme of physics. Hence, its assumption of a physical inherent impossibility of learning more about an experimental situation has represented in a self-prophesying way only an impediment for further research into the matter. Doubts emerge on whether the complementarity postulate is a scientific statement, or an unwarranted physical and epistemological assumption. Actually, both the Bohr and EPR views are based on too close a reliance on classical tenets, assumed to be the necessary language of natural phenomena, and which have been held sacred, as in the case of the concept of space\textsuperscript{1}. Yet the preeminence of quantum phenomena suggests classical concepts need not be the only way to describe experiments. Also, the argument we have presented above implies the standard interpretation of QM is not satisfying and must be modified and it supports the opinion that the accepted concepts of the wave function and/or space are suspect.

\textsuperscript{1}This statement should be understood literally in the case of Newton.
In this paper we propose a new interpretation of the wave function which requires a modification of the concept of space used in its description, and in which both space and the wave function are assumed to be related. In Section II we make a brief historical review of the concepts of space and also an analysis of its current conceptions in modern theories, and in particular, QM’s use of configuration space and physical space. In Section III, we ponder some consequences of the assumption that the latter two are not equal. In particular, this idea constitutes a possible solution to the problem of non-locality in QM. We consider also the implications of the proposal that the wave function and space are related in connection to the incompatibilities in modern-theories’ conceptions of space. The new interpretation also motivates a new formulation of field equations on an extended spin space, in Section IV, providing a unified description of bosons and fermions. In Section V we draw some conclusions.

2 A brief history of space concepts, and current ones

A persistent puzzle through the centuries has been the nature of space and its relation to physical phenomena. Controversies have arisen both around its form, whether it is finite or infinite, open or closed, and its substance, whether it is continuous or discrete, empty or full, and ultimately whether it represents at all any physical phenomenon. A closely related debate to the latter question is the relation of space to the matter that moves in it. This debate can be summarized into two differing views. In the “monistic” view space is inseparable and indistinguishable from the matter that exists in it, and the distinction between space and matter is simply a

\[2\] That is, related to something one can measure.
question of convention. In the “reductionistic” view space is of a wholly different nature from matter, if at all, and is mainly the receptacle where bodies exist. While the first view is aesthetically and philosophically more appealing as it conforms to a unified view of nature, the second is artificial but more intuitive, and has been more successful and useful, by providing a simple framework, or stage, to treat phenomena, as in Newtonian mechanics in contrast to Cartesian. However, while within the first view space has a physical meaning doubts remain on whether this is the case for the second view. For example, Leibnitz argued in this direction by stating that space is only a system of relations between bodies.

In the nineteenth century the debate centered around the newly introduced field concept, needed to account for extended phenomena through space, coming from a novel understanding of electromagnetism by Faraday. Formalization of this concept in Maxwell’s equations resulted in an understanding of light as an extended electromagnetic perturbation through space. Analogy of the behavior of light with that of other waves in other media led physicists to conclude that space was a medium, the ether, an assumption which supported the monistic view. In a Galilean framework, this medium would define a preferred frame of reference for the universe. Special relativity (SR), however, avoids giving special significance to any particular reference frame through a new understanding of time3, and yet accounts for electromagnetic phenomena. Thus, it deprives space again of any relevance except for providing for the stage where events occur. This theory then generalizes the Newtonian view of space and time into the Minkowskian framework, but keeps the basic feature of using coordinates to identify the physical but otherwise inert points of space and time which define the bodies’ position.

In the twentieth century the debate has continued as the accepted theories of na-

3We shall not discuss the conceptions of time, although as implied here, they do have an influence on the evolution and perception of theories.
ture subscribe to both views. This is the case of GR, in which the local and global manifestations of space are considered physical. On the one hand, it is inherent to this theory that, at the local level, space-time is as a Minkowskian physical framework, or *stage*, in which objects fall freely and physical phenomena are the same as in flat space, independently of the particular spot in which they occur (second view). On the other hand, at the global level space-time is a manifold described by the metric *field*, which embodies gravity, and it is coupled to matter. Here *coordinates* are labels to account for particular points in the manifold but any particular choice lacks physical significance. (This is expressed by the coordinate invariance of GR).

The inseparability of space, the gravitational field and matter gives space the status of a physical object (first view). The understanding of space as a *field* strongly suggests a link to electromagnetic phenomena. This possibility was explored by Kaluza and Klein who, by extending space to more dimensions, constructed a model which encompasses both four-dimensional space-time and another dimension accounting for the electromagnetic field.

Classical (CM) and quantum mechanics subscribe to the second view. In QM, the wave function, which contains all the information of the matter it describes, is defined as a field. The same is true in QFT, which describes varied numbers of particles by allowing for an infinite number of degrees of freedom represented by its principal element, the quantum field. The latter has space-time as a parameter and satisfies causality constraints from SR. However, there is an ambiguity inherent to the quantum mechanical treatment with regard to the physicality of space. On the one hand, the wave function’s expression in configuration space represents merely a basis choice and is by no means compulsory; indeed, momentum space is another possible basis, which means one is not more relevant than the other (the incompatibility of these bases leads to Heisenberg’s uncertainty relations). On the other hand, the association of a particle with a given position comes only after the wave function is “collapsed” on that point, that is, when a measurement is carried out.
3 Wave function and space integral view

The association of QM’s configuration-space basis of the wave function and space, which has been assumed natural, is by no means obvious or necessary. Thus, one can deprive these coordinates from their stage meaning. A notable implication from this separation assumption is a possible solution to the EPR paradox and Bell’s implied non-locality, for distance loses its universality. A whole set of possibilities for new conceptions opens up, although these should be restrained by the requirement of causality and locality, whose successful consequences in QFT do not enjoin their renunciation. One possible path to follow is that if configuration space is deprived of a direct association with physical space, having only an ascribed meaning of basis coordinate, the remaining physical quantity left in the quantum mechanical description, the wave function, must contain the complete information on both matter and space. We call integral this view of space and the wave function.

Generally, under the conception of space as field, as in global GR, and in QM and QFT—which deny any physical meaning to a well-defined place where objects are—coordinates play merely a descriptive role. But under the conception of space as stage, as background of events in the local description of GR, and in CM, QM, and QFT (after a measurement is performed), coordinates are ascribed a physical meaning.

Thus, the above proposal overcomes the incommensurable uses of coordinates in the field and stage descriptions of space, underlines their use of as a pure bookkeeping device, and fits a preferable unified view of space as field and the idea that space is not void but is a manifestation of a “space-matter” substance.

With the identification of the wave function with space, the latter acquires a field meaning, described by coordinates, whose stage meaning is dropped. Hence, by subscribing to the view that the wave function, which describes matter, fills up space
we dispose of space as *stage* at the local level too. In this way, we are emulating the treatment of global GR by interpreting the wave function (space) as the relevant field, whose coordinates do not have a direct physical meaning; at the same time we apply this idea at the local level, which GR does not do. This idea therefore brings QM and GR nearer and allows for a removal of an inconsistency in an entirely new framework which gives space a new meaning locally. However, the analogy between GR’s space and QM’s configuration space is only partial, given that the multiplicity of particles requires in principle a multiplicity of configuration coordinates. Also, while a coordinate in GR describes a given space-time point with a given metric property, in the proposed QM interpretation all physical meaning is assigned to the wave function and coordinates become labels with the possibility of redundancy in the description. We may expect that in the classical limit space regains its usual meaning of *stage*. The connection to this description should come through average quantities such as the two-particle density-matrix.

4  **Boson and fermion field equations on an extended spin space**

A shared description is expected in a unified treatment of the wave function and space. Hence, it is plausible to have fermions and space, whose representing field, the graviton, is a boson, under the same footing. This suggests a closer connection between fermions and bosons, and in general, matter fields under the same footing as interaction fields. To implement this idea we need a formalism that relates a field to the very structure of space-time: this link is present at a fundamental level for fermions through Dirac’s equation and its related matrices, which use the simplest $SO(3, 1)$ representation. Through these matrices we expect a link between the sym-
metry of space-time, and the fermions that the equation describes, that is, a link between the structure of space and matter. To the extent that this description can include bosons we hope some information will be obtained about gauge interactions and their vector particles, and eventually, about spin-two particles, the carriers of gravitation. Indeed, while the ultimate goal of a unified theory may be to construct it as encompassing that the curvature of space in GR be linked to the wave function, at present we concentrate on a more modest Lorentz-invariant approach using Minkowski’s space-time. Thus, we search for a description of vectors and scalars as close as exists for fermions in order to be able to relate both representations. We also demand that the field equation which provides such description be enclosed in a variational principle framework. These requirements are attained by generalizing Dirac’s equation and by extending its multiplet content. Then, instead of assuming the Dirac operator acts on a spinor

\[(i\partial_\mu \gamma^\mu - M)\psi = 0,\] 

where \(\psi\) is the column vector with components \(\psi_\alpha\), we assume it acts on a \(4 \times 4\) matrix \(\Psi\) with components \(\Psi_{\alpha\beta}\), so that the equation becomes

\[(i\partial_\mu \gamma^\mu - M)\Psi = 0.\] 

There are, then, additional possible transformations and symmetry operations that further classify \(\Psi\). The Dirac-operator transformation \((i\partial_\mu \gamma^\mu - M) \rightarrow U(i\partial_\mu \gamma^\mu - M)U^{-1}\) induces the left-hand side of the transformation

\[\Psi \rightarrow U\Psi U^\dagger,\] 

and \(\Psi\) is postulated to transform as indicated on the right-hand side. Thus, all symmetry operators valid for the Dirac equation in eq. \[\] (with its corresponding particular cases of massless and massive cases) will be valid as well for it. The operators therefore satisfy the Poincaré algebra.
That the equation, the transformation and symmetry operators \( U \), and the solutions \( \Psi \) occupy the same space is not only economical but it befittingly implements quantum mechanics, for it ultimately implies measuring apparatuses are not constituted differently in principle from the objects they measure.

\( U \) and \( \Psi \) can be classified in terms of Clifford algebras. In four dimensions (4-d) \( U \) is conventionally a \( 4 \times 4 \) matrix containing symmetry operators as the Poincaré generators, but it can contain others, although, e. g., in the chiral massless case it can only carry an additional \( U(2) \) scalar symmetry. More symmetry operators appear if Eq. 2, \( \mu = 0, ..., 3 \), is assumed within the larger Clifford algebra \( \mathcal{C}_N, \{\gamma_\mu, \gamma_\nu\} = 2g_{\mu\nu}, \mu, \nu = 0, ..., N - 1 \), where \( N \) is the (assumed even) dimension, whose structure is helpful in classifying the available symmetries, and which is represented by \( 2^{N/2} \times 2^{N/2} \) matrices. The usual 4-d Lorentz symmetry, generated in terms of \( \sigma_{\mu\nu} = \frac{i}{2}[\gamma_\mu, \gamma_\nu], \mu, \nu = 0, ..., 3 \), is maintained and \( U \) contains also \( \gamma_a, a = 4, ..., N - 1 \), and their products as possible symmetry generators. Indeed, these elements are scalars for they commute with the Poincaré generators, which contain \( \sigma_{\mu\nu} \), and they are also symmetry operators of the massless Eq. 2, bilinear in the \( \gamma_\mu \) matrices, which is not necessarily the case for mass terms (containing \( \gamma_0 \)). In addition, their products with \( \gamma_5 = -i\gamma_0\gamma_1\gamma_2\gamma_3 \) are Lorentz pseudoscalars. As \( [\gamma_5, \gamma_a] = 0 \), we can classify the (unitary) symmetry algebra as \( S_{N-4} = S_{(N-4)R} \times S_{(N-4)L} \), consisting of the projected right-handed \( S_{(N-4)R} = \frac{1}{2}(1 + \gamma_5)U(2^{(N-4)/2}) \) and left-handed \( S_{(N-4)L} = \frac{1}{2}(1 - \gamma_5)U(2^{(N-4)/2}) \) components.

The solutions of Eq. 2 do not span all the matrix complex space, but this is achieved by considering also solutions of

\[
\Psi\gamma_0(-i\partial_\mu \gamma^\mu - M) = 0, \tag{4}
\]

consistent with the transformation in Eq. 3. (the Dirac operator transforming accordingly).

It is not possible to find always solutions that simultaneously satisfy equations of
the type II and IV (except trivially), which means they are not simultaneously on-shell, but they satisfy at least one and therefore the Klein-Gordon equation. Indeed, the solutions of eqs. II and IV can be generally characterized as bosonic since $\Psi$ can be understood to be formed of spinors as $\sum_{i,j} a_{ij} |w_i\rangle \langle w_j|$. Generalized operators acting on this tensor-product space (spinor × spinor × configuration or momentum space) further characterize the solutions. Positive-energy solutions, according to Eq. II are interpreted as negative-energy solutions from the right-hand side. This problem is overcome if we assume the hole interpretation for the $|w_j\rangle$ components, which amounts to the requirement that operators generally acting from the right-hand side acquire a minus, and that the commutator be used for operator evaluation. Thus, the 4-d plane-wave solution combination $\frac{1}{4!}[(1 - \gamma_5)\gamma_0(\gamma_1 - i\gamma_2)]e^{-ikx}$, with $k^\mu = (k, 0, 0, k)$, is a massless vector–axial ($V - A$) state propagating along $\hat{z}$ with left-handed circular polarization, normalized covariantly according to $\langle \Psi_A | \Psi_B \rangle = tr\Psi_A^\dagger \Psi_B$, the generalized inner product for the solution space. In fact, combinations of solutions of Eqs. II and IV can be formed with a well-defined Lorentz index: vector $\gamma_0\gamma_\mu$, pseudo-vector $\gamma_5\gamma_0\gamma_\mu$, scalar $\gamma_0$, pseudoscalar $\gamma_0\gamma_5$, and antisymmetric tensor $\gamma_0[\gamma_\mu, \gamma_\nu]$. For example, $A_\mu^C(x) = \frac{1}{2}\gamma_0\gamma_\mu e^{-ikx}$ is a combination that transforms under parity into $A_\mu^C(\tilde{x})$, $\tilde{x}_\mu = x^\mu$, that is, as a vector. We may also view $\frac{1}{2}\gamma_0\gamma_\mu$ as an orthonormal polarization basis, $A_\mu = tr\frac{1}{2}\gamma_\mu A^\nu\frac{1}{2}\gamma_\nu$, just as $n_\mu$ in $A_\mu = g_{\mu\nu}A^\nu = n_\mu \cdot A^\nu n_\nu$. In fact, the sum of Eqs. of II and IV implies IV for a $\Psi$ containing $\gamma_0A = A^\mu\gamma_0\gamma_\mu$ that $A^\mu$ satisfies the free Maxwell’s equations.

Solutions contain also products of $\gamma_a$ matrices that define their scalar-group representation. For given $N$, there are variations of the symmetry algebra depending on the chosen Poincaré generators and Dirac equation, respectively, through the projection operators $\mathcal{P}_P$, $\mathcal{P}_D \in S_{N-4}$, $[\mathcal{P}_P, \mathcal{P}_D] = 0$. $\mathcal{P}_P$ acts as in, e.g., $\mathcal{P}_P\sigma_{\mu\nu}$, and $\mathcal{P}_D$ 4As for $\bar{\psi} = \psi^\dagger\gamma_0$, a unitary transformation can be applied to the fields and operators to convert them to a covariant form.
modifies Eqs. 2 and 4 through $P_D \gamma_0 (i \partial_\mu \gamma^\mu - M)$. Together, they characterize the Lorentz and scalar-group solution representations. We require $\text{rank} P_D \leq \text{rank} P_P$, for otherwise pieces of the solution space exist that do not transform properly. For $P_D \neq 1$ Lorentz operators act trivially on one side of the solutions containing $1 - P_P$, since $(1 - P_P) P_P = 0$, so we achieve the goal of having fermions in a common description with bosons.

An interactive field theory can be constructed in terms of the above degrees of freedom. We consider a vector and fermion non-abelian gauge-invariant theory. The expression for the kinetic component of the Lagrangian density

$$L_V = -\frac{1}{4} F^{a \mu \lambda} \gamma_0 \delta_{ab} F_{b \mu \eta} = -\frac{1}{4 N_o} tr P_D F^{a \mu \lambda} \gamma_0 \gamma^\lambda G_a F_{b \mu \eta} \gamma_0 \gamma_\eta G_b$$

(5)

shows $L_V$ is equivalent to a trace over combinations over normalized components $\frac{1}{\sqrt{N_o}} \gamma_0 \gamma_\mu G_a$ with coefficients $F^{a \mu \nu} = \partial_\mu A^{a \nu} - \partial_\nu A^{a \mu} + g A^{b \mu} A^{c \nu} C^{a}_{bc}$; $g$ the coupling constant, $\gamma_\mu \in C_N$, $G_a \in S_{N-4}$ the group generators, $C^{a}_{bc}$ the structure constants, and $N_o = tr G_a G_a$, where for non-abelian irreducible representations we use $tr G_i G_j = 2 \delta_{ij}$.

Similarly, the interactive part of the fermion gauge-invariant Lagrangian $L_f = \frac{1}{2} \psi^\dagger \gamma_0 \mu A^{a \mu} G_a \gamma^\mu \psi^a$, with $\psi^a$ a massless spinor with flavor $a$, can be written $L_{\text{int}} = -g \frac{1}{2 N_o} tr P_D A^{a \mu} \gamma_\mu G_a \gamma_0 \gamma_\lambda G_b$, with $j^{a \alpha} = \frac{1}{2} tr \Psi^\dagger \gamma_0 \gamma_\mu G_a \Psi^a$ containing $\Psi^a = \psi^a \langle \alpha \rangle$, and $\langle \alpha \rangle$ is a row state accounting for the flavor. $L_{\text{int}}$ is written in terms of $\gamma_0 A^\mu$ and $\gamma_0 j^{a \alpha}$, that is, the vector field and the current occupy the same spin space. This connection and the QFT understanding of this vertex as the transition operator between fermion states, exerted by a vector particle, with the coupling constant as a measure of the transition probability, produces information on the coupling constant $[8, 10]$.

As for the initial formulation, $P_D$ restricts the possible gauge symmetries that can be constructed in the Lagrangian, for $\gamma_\mu G_i$ needs to be contained in the space it projects. Thus, $P_P$ and $P_D$ determine the symmetries, which are global, and in turn, determine the allowed gauge interactions. Furthermore, they fix the representations,
assumed physical. The $N = 6$ case has been researched and connections have been found to the $SU(2)_L \times U(1)$, electroweak sector of the SM. As a result, restrictions are provided on the representation choices, vertices, and coupling constants. Relevant information on the standard-model representations and interactions is obtained from the 10-$d$ case.

Thus, the extended Dirac equation in Eq. 2, the Bargmann-Wigner equation, and the expression for a standard Lagrangian as in Eq. 3 have in common that fields are formulated on an extended spin space, with the possibility of relating some generators in this space to scalar degrees of freedom. This is a limited but significant example of a consistent generalization that connects the space-time and scalar symmetries, giving a unified description of boson and fermion fields. It suggests a research direction for an ultimate formalism describing space and the particles’ wave function in a unified way.

5 Conclusions

In this paper we have proposed an interpretation of QM in which its non-local correlation paradoxical aspect, implied by Bell’s inequalities, is removed. This entitles a separation of the concept of space as basis, used in the description of the wave function, and physical space; then, only the wave function assumes a physical meaning and it encompasses both space and matter. Our proposal is both radical and conservative for it advocates a modification of the notion of space which has been assumed untouchable, and yet, it has the aim of satisfying locality, thus explaining instantaneous correlations. The idea presented goes beyond being only a conceptual interpretation for it motivates a formulation of field equations that has relevant consequences in particle physics and embodies this interpretation well. We do not claim that within this interpretation all QM paradoxical aspects will go away for clearly
this requires dealing with the problem of the collapse of the wave function, which is presently under intense experimental and theoretical research. Rather, we advocate another conceptual framework in which problems as the collapse of the wave function and randomness can be confronted afresh.

The approach thus presented also generally implies that in dealing with QM’s old problems a researcher armed with mathematical tools, his imagination, and a disposition to question classical tenets could rehabilitate investigations whose aim of picturing what is going on in quantum phenomena has not been considered productive. Thus, for example, we speculate that within such an approach the fact that the system is inescapably perturbed would be just a natural consequence, and not something that would impede our capacity for forming a picture of events. Also, Heisenberg’s uncertainty relations would be interpreted as not limiting our knowledge of reality, as commonly understood, but only our expectations about how this knowledge should be.

The pervasiveness and physical nature of the wave function have been proven in innumerable cases. The arguments presented in this paper imply a negative answer to the question “Is the wave function different from space?” constitutes a viable interpretation of quantum mechanics that solves some of its puzzles. This interpretation allows for its simplicity to be kept by using the framework of space-time coordinates, while these are stripped of any direct physical meaning.

The scientific quest for a unified description of nature is as ancient as the early Greek philosophers who conceived the concept of apeiron, a primordial matter of which objects are constituted. The interpretation presented here brings closer a description of the wave function and the space-time it is supposed to traverse. Having the fields stemming from a single coordinate base brings us closer to the idea that the (matter and carrier) fields are but aspects of a single entity.

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