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The wrong foundation of quantum mechanics

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Abstract.-This paper discusses the incompatibility between the formal logic derived from quantum phenomenology and the ordinary logic that underlies the mathematics constituting the formal language of quantum mechanics. A new discrete scenario in which this incompatibility could be resolved is also proposed.

Keywords: EPR paradox, GHZ states, laws of ordinary logic, discrete magnitudes, discrete space, discrete time, cellular automata.

1 From EPR to GHZ

As is well known, and according to the Copenhagen interpretation (CI), quantum mechanics assumes the coexistence (superposition, merge) of mutually exclusive states in quantum systems until a measurement is performed on them. It is also well known that in 1935 a famous article was published that pointed to the non-completeness of this interpretation of quantum mechanics [6, p. 780]:

> Previously we proved that either (1) the quantum-mechanical description of reality given by the wave function is not complete or (2) when the operators corresponding to two physical quantities do not commute the two quantities cannot have simultaneous reality. Starting then with the assumption that the wave function does give a complete description of the physical reality, we arrived at the conclusion that two physical quantities, with non-commuting operators, can have simultaneous reality. Thus the negation of (1) leads to the negation of the only other alternative (2). We are thus forced to conclude that the quantum-mechanical description of physical reality given by wave functions is not complete.

Some years later, in 1964, another famous paper was published [4] in which its author J. Bell (closer to Einstein than to Bohr) proved the famous theorem that bears his name, and which makes it possible to test in experimental terms whether the inequalities included in the theorem are violated or not. The experiments took some time to arrive, but they arrived in 1982 [3, 2], 1998 [20], 2001 [9] and in all cases the violation of Bell's inequalities was confirmed, which gave the reason to Bohr's CI to the detriment of the previous argument of Einstein, Podolsky and Rosen (EPR).

In 1990 a remarkable simplification of Bell's argument was published that avoided its inequalities, a simplification also testable in experimental terms but avoiding Bell's statistical cumbersomeness [8]: the GHZ states (by Greinberger, Horne and Zeilinger). Also in this case the corresponding experiments ended up being carried out [5], which, again, gave the reason to Bohr's CI. Since these last experiments, most authors consider the historical Bohr-Einstein dispute to be over. Here we will analyze the reasons why this might not be the case.

But first it is worth recalling the chaotic use of (ordinary) language that characterizes contemporary physics, a problem already denounced in 2015 by T. Maudlin [16, p. xiv]:

> Unfortunately, physics has become infected with very low standards of clarity and precision on foundational questions, and physicists have become accustomed (and even encouraged) to just "shut up and calculate", to consciously refrain from asking for a clear understanding of the ontological import of their theories.

Indeed, it is normal in today's physics to find contradictory uses of language. For example, the word "something" meaning the same as the word "nothing"; or the word "empty" the same as the word "full". In the EPR-GHZ case we are dealing with, it is very common to find things such as [1, p. 5]:

> For example, on a subatomic scale, individual particles communicate with each other instantaneously despite being far apart, which defies common sense.

Which obviously does not occur, since the subatomic particles are not informed systems [11], they do not elaborate, nor transmit, nor receive, nor interpret information. What corresponds to say is that, according to CI, there seem to be instantaneous influences between the entangled particles; or acausal effects, not locally deterministic, between those particles.

It has also been said that ordinary logic is not the logic of quantum mechanics (e.g. [7, p. 60]). In this connection it is worth recalling E. Schrödinger's (who was also not a supporter of CI) and his famous cat [18, §5]. We can indeed affirm [14]:

P: There is a living being inside Schrödinger's box.

Q: No living being can be at the same time alive and not alive.

Consequently:

$$\mathbf{CI} \wedge \mathbf{P} \implies \neg \mathbf{Q}$$

which implies the violation of the Second Law of ordinary logic.

It might then be true that ordinary logic is not the logic of quantum phenomena. But then a new problem arises because the two fundamental laws of ordinary logic (the Principle of Identity and the Law of Non-Contradiction) are in fact fundamental laws of the mathematics with which quantum mechanics is constructed. Consequently, CI would imply the use of a logic in its mathematical language that is not the logic of the phenomena it describes. One could then speak of a *wrong foundation of quantum mechanics*.

Before proposing the new scenario in which this wrong foundation of quantum mechanics could be resolved, it will be necessary to deal, albeit very briefly, with some formal issues related, above all, to the nature of mathematical infinity and to the ontological nature of physical space.

2 An infinity never questioned

Throughout the centennial history of quantum mechanics, there have been, and still are, intense debates about various aspects of the theory, but as far as I know, there has never been a discussion about what should have been the first point to be discussed: the hypothesis of the actual infinity subsumed in the Axiom of Infinity that underlies the mathematics of quantum mechanics itself. Having been one of the most discussed hypotheses in the history of human thought, it is very strange that it has not been discussed for more than a century, since it was axiomatically assumed by modern set theories.

These set theories have finally provided instruments that allow us to analyze the inconsistency of the actual infinite, as is the case of the ω order of the natural numbers, or the dense order of the rationals and the reals. The spacetime continuum is one of those infinite sets whose elements are densely ordered and which allow us to construct proofs of their own inconsistency, such as the one included in this section. An inconsistency that physicists should be interested in, given the omnipresence of the spacetime continuum in a good part of their theories, including quantum mechanics. But this is not the case, nor can I think of what to do to make it so. At least I invite the reader to consider the following proof, which will take only a couple of minutes:

(The next theorem is a very abbreviated version of the argument [12, p. 59-63 Link], where the reader can find another 40 different proofs.)

Theorem 1 *The Axiom of Infinity is inconsistent.*

Proof.-The interval of rational numbers $\mathbb{Q}_{01} = (0, 1)$ is denumerable and densely ordered. So, it can be put in one-to-one correspondence f with the set $\mathbb{N}$ of natural numbers in their natural order of precedence; and $\mathbb{Q}_{01}$ can be rewritten as the set $\{f(1), f(2), f(3), \dots\}$. Let now x be a rational variable initially defined as $f(1)$; and let (the current value of) x be compared with the successive elements $f(1)$, $f(2)$, $f(3)\dots$ so that x is redefined as $f(i)$ if, and only if, $f(i)$ is LESS THAN the current value of x. Since, according to the Axiom of Infinity, all elements $f(1), f(2), f(3), \dots$ of $\mathbb{Q}_{01}$ are rational numbers which exist as a COMPLETE TOTALITY, x can be successively compared with ALL of them:

$$\begin{aligned}&\forall n \in N: \ x \text{ is compared with } f(n), \text{ and}\\ &\text{redefined as } f(n) \text{ iff } f(n) < x\end{aligned} \tag{1}$$

Once compared with all elements[1] of $\mathbb{Q}_{01}$, the current value of x is the smallest rational of that set. Indeed, if once compared with all elements of $\mathbb{Q}_{01}$, the current value of x were not the least rational of $\mathbb{Q}_{01}$, there would exist at least one element $f(n)$ in $\mathbb{Q}_{01}$ such that $f(n) < x$. But this is impossible according to (1). Therefore, it was compared with $f(n)$ and redefined as $f(n)$. So, it is impossible that $f(n) < x$. But it is also immediate to prove that: Once compared with all elements of $\mathbb{Q}_{01}$, the current value of x is not the smallest rational of that set. In effect, once compared with all elements of $\mathbb{Q}_{01}$, and whatsoever be the current value of x, each element of the infinite set $\{x/2, x/3, x/4 \dots\}$ is an element of $\mathbb{Q}_{01}$ less than x. This contradiction proves the Axiom of Infinity legitimizing the existence of $\mathbb{Q}_{01}$ as an actual (not potential) infinite totality is inconsistent. Or in other words: a COMPLETE and ordered list, such as the rational interval $(0, 1)$, without a first element that starts the list is inconsistent. □

3 The reality of physical space

In 2007, and therefore 8 years before the first empirical detection of gravitational waves, R. Laughlin wrote [10, p. 158]:

> Subsequent studies, carried out with large particle accelerators, helped to understand that space is more like the glass of a window than Newton's ideal vacuum: it is full of "stuff"that is normally transparent but can be made visible if struck with sufficient force to dislodge a part of it. In contemporary physics, the vacuum of space is understood as a relative ether, a conception that is confirmed every day experimentally but which does not receive that name because it is taboo.

From 2015 to date, there have been about 100 episodes of empirical detection of gravitational waves in the global network of interferometers (LIGO, Virgo, GEO600, TAMA). Of course, about these detections it is possible to say [15, p. 2]:

> Of course, gravitational waves are real vibrations that produce real effects in real instruments made of real ordinary matter. Consequently, the vibrating medium, space, must also be real. What does not exist can neither vibrate nor physically interact with ordinary matter. In my opinion, this reality of physical space is the most important consequence of the empirical detection of gravitational waves, although, as far as I know, it has not even been considered. [...] And like any real physical entity, space will have its own substantiality, which, for simplicity, I will call space matter.

[1] Though it is not necessary, this is formally proved by induction in [12], and can also be proved by Modus Tollens and by supertask theory.

It is surprising then that in spite of the overwhelming evidence of its physical reality, the majority of physicists still think that physical space is not real, that it is only a fiction useful to express certain relations between material physical objects. A fiction that, on the other hand, must be elastic, more rigid than metals, extensible, deformable, vibrating and propagating its own vibrations and the corresponding energies.

The scenario in which the wrong foundation of quantum mechanics introduced above could be solved, includes the reality of physical space, the existence of a sort of space matter. A space matter that, according to everything we know about the physical world, must be different from ordinary matter (baryonic cold matter) and transparent to this ordinary matter (Principle of Inertia), which implies that both matters can coexist and cease to coexist in the same places.

4 Discrete magnitudes

Energy (of any kind), mass, electric charge and color charge are discrete magnitudes with indivisible minimum values (quanta). Consequently, any mathematical function whose output is one of those discrete magnitudes must give a result compatible with the discreteness of the corresponding discrete magnitude: the result (the output) of that function can only be an integer multiple of the quantum (indivisible minimum) of that discrete magnitude. As far as I know, physicists have not paid attention to this requirement of discreteness, and invariably they use continuous functions of continuous output when that output should be discrete, because it must be the value of a discrete magnitude.

Naturally, continuous variables cannot enter a discrete output function (the output would always be continuous). However, it happens that in many functions whose output is the value of a discrete magnitude, for example energy, continuous variables such as space, or time, or both (velocity) intervene. In these cases it is not possible to obtain the discrete outputs that should be obtained. It is only possible to obtain discrete outputs of a mathematical function if all the variables of that function are discrete variables (see the last paragraph of this section). Therefore, any consistent physical theory must take this restriction into account.

An immediate consequence of this restriction is that both space and time must be discrete magnitudes, with indivisible minima (quanta), which could be called qseats for space and qbeats for time. In this model, which is discrete and consistent with the discrete magnitudes (energy, mass, charge, electric charge, etc.), the following requirements (among others) must be verified [13, p. 2]:

1. Nothing can be smaller than a quantum of space (qseat).
2. Nothing can last less than a quantum of time (qbeat).
3. There is a maximum speed of a qseat per qbeat.
4. Any physical object maintains its state for at least one qbeat.
5. All physical processes, including motions, must be discrete, not continuous, which is how we perceive them.

The strange thing about quantum mechanics is that it is a physical theory about an essentially discontinuous physical world, but developed with a continuous, non-discrete, mathematical language. Which, for the reasons just given, is not formally acceptable: the discrete outputs of mathematical functions cannot be continuous. Consequently, those discrete output functions cannot be fed with continuous variables, which is the case in contemporary quantum mechanics.

As far as I know, this incompatibility between continuous mathematical functions and the necessary discreteness of their outputs has never been considered. Neither has the problem of the arithmetic compatibility of the different quanta of the different discrete magnitudes, a compatibility necessary for all the outputs of all the functions that relate them to be discrete. A new and exciting quantum problem to be solved. A very simple, and also very speculative, solution is that all quanta of all physical magnitudes are integer multiples of a universal minimum magnitude.

5 A quantum local universe

It does not seem reasonable to assume one logic for quantum phenomenology, and a different logic for the mathematical language with which this phenomenology is expressed. But that is exactly what happens with some interpretations of quantum mechanics, as is the case with the most commonly accepted of them all: the Copenhagen interpretation (CI). If classical logic is not valid for CI, it should not be valid for its mathematical language either. There should be the same fundamental logic for both. Until this situation is resolved, we will have to admit an incorrect foundation of quantum mechanics.

About mathematics, it is worth remembering that it is inconsistent due to the hypothesis of the actual infinity that axiomatically founds it. Therefore, all branches of mathematics should be finitist. With respect to the CI-type interpretations of quantum mechanics, a question seems inevitable: can a science be incompatible with the Second Law of logic? According to that law, an atom cannot be at the same time disintegrated and not disintegrated, nor can it be successively disintegrated and not disintegrated, because once it disintegrates it cannot disintegrate again. It is important to remember that the violation of the Second Law of logic makes it possible to prove any proposition, so that the corresponding violating theory would be anything but a consistent scientific theory.

Perhaps the only legitimate consideration is the consideration of the whole universe as a single object evolving directionally in the sense of its isotropization, i.e. in the sense of its entropy increasing. A directional evolution that has been producing the same objects (galaxies, stars, etc.) for billions of years, and has been doing so without observers collapsing the state superpositions of the quantum objects involved. Perhaps experimental quantum strangeness only occurs in the realm of laboratory and thought experiments detached from the universe as a whole. The superposition of the living and non-living state of a living being is incompatible with known organic nature. And if that superposition is linked to the *disintegrated atom/non-disintegrated atom* superposition, the latter would have to collapse with the presence of the cat and the rest of the setup of Schrödinger's famous thought experiment, otherwise the Second Law of logic would be violated.

A new perspective for quantum phenomena could be offered by cellular automata (CAs), of which there is already at least one model developed along these lines [19], albeit with the same inconsistent mathematics of the actual infinity. As in CAs, quantum objects could somehow be present, and in periodically varying ways, in all qseats in the universe. Their presence in qseats could add and subtract giving rise to constructive and destructive interferences. A new perspective to explain wave-corpuscle duality.

On the other hand, every observation is an interaction that has to be included in the explanation, and that can cause changes in the observed objects (collapse of the wave function). The wave presence of quantum objects would collapse with observational interactions. Moreover, the entangled objects could be considered as a single object, so they would vary simultaneously. This could be a new perspective to explain the instantaneous influence at a distance and the quantum indeterminism linked to entanglement.

The recursive functioning of CAs and their evolution in unison, as a whole, could also be the cause of the emergence of nonlinear dynamics, of new objects, and of new laws governing their evolution. Thus, the functioning of a CA could serve to explain certain behaviors of the quantum world and of the universe that so far seem inexplicable to us. We would also have a CA version of Bhor's Principle of Complementarity: the behavior of individual qseats versus that of the objects of the CA defined by those qseats. And in addition to objects, the contents of the qseats would also define the different CA force fields.

Despite the CA proposal for quantum mechanics cited above, there is still much work to be done in this regard. One should even consider the role of computational languages in CA models. Problems may arise when extrapolating observations and conclusions about the world of macroscopic physical objects to the world of subatomic contents of CA qseats. The former emerge from the latter. We would have two levels of laws: those of the CA and those of the emergent objects:

> ... and the structure of the everyday objects is emergent from quantum mechanical events. [17, p. 97].
>
> From the perspective of emergentism, physical laws are rules of collective behaviour that follow from more primitive behaviour rules. [10, p. 111]

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