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Measurement Problem and Non-Locality: An Alternative Interpretation

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Abstract

The Measurement problem and Non-locality are classical problems in Quantum Mechanics and still unsolved in spite of the many proposed solutions. A new interpretation is proposed here, based on the idea that they are closely related problems. But it requires that we consider space and time not as objective mediums but as features of our representation of reality, as Kant explained more than two centuries ago.

Keywords

Superposition of States, Wave Function Collapse, Actual and Potential Positions, Probability, Entangled Particles, Action at a Distance, Instantaneous Effect

1. Introduction

When a quantum object is not observed, it is wavelike: it is not in one determined state and position, but in a superposition of more or less probable states and positions, described by its wavefunction. But, according to the Copenhagen Interpretation, when it is "measured", i.e. when it is observed, when it physically interacts with the observation device, its wavefunction collapses and it passes from a plurality of more or less probable states and positions to one determined actual state and position.

This mysterious phenomenon, called the "Measurement problem", puzzles the physicists from the start of Quantum Mechanics. Several explanations have been proposed: De Broglie and Bohm's "Hidden variables", Everett's "Multiverse", Spontaneous Collapse theory, Consistent histories, etc., but none has been unanimously accepted (Albert, 1992; Hance & Hossenfelder, 2022; Myrvold, 2022).

Maybe the reason is, as it sometimes happens, that the authors did not look for the solution in the right place. As could be expected, they reasoned as physicists and tried to solve the problem in their usual paradigmatic frame and in their native language, mathematic formalism. In other words, the proposed explanations are all on the technical side, and they imply the unquestioning acceptance of the existing philosophical paradigm. But it could be that the solution is somewhere upstream, in the implicit philosophical assumptions on which this paradigm is based, notably its understanding of space and time. This is anyway what will be argued here.

Among these implicit assumptions, it seems that there exists an untold consensus about the objective existence of space and time, which are considered as observer-independent features of reality (Savitt, 2021). As a consequence, reality is considered spatio-temporal.

The argument is as follows: if I am perceiving something there is reason to think that this something exists objectively out there, independently of me, that it is real. And if it is real, it is in space and time, as everything which I perceive: reality is spatio-temporal. Without being fully conscious of it, I thus implicitly identify what I perceive with what is.

But it is necessary to make a distinction between before and after the act of perceiving. Before, we do have an objective, observer-independent reality out there. But after, this exterior reality has been interiorized by the observer and transformed into a spatio-temporal representation. This representation is his own, it has been created by him, depending on his particular physical relationship with reality and on the properties of his sensory apparatus. This means that it does not exist independently of him: what he perceives is not reality, it is his interpretation of reality. Assuming that reality is spatio-temporal is assuming that it is identical with its representation—it is mistaking what is represented for what is. And this is the key to understanding the measurement problem.

Let us consider a moving object in the macroscopic world. Its movement looks continuous. But what is perceived as continuous is in fact a discontinuous succession of still positions following each other at a certain frequency. There is a consensus among specialists about the fact that a stimulus must last about $1/10^{th}$ of a second to be perceived (Walker, 2000). The object is then perceived at rest in A during $1/10^{th}$ of a second, then at rest in B, etc.

But it is not perceived between A and B. It is perceived only when it is at rest in A and in B. Yet it was there since it travelled from A to B. This can be proven: if the observer uses a high speed camera he will find the object in a number of intermediary positions—which he does not perceive with the naked eye. But however high the speed of the camera, a millionth or a billionth of a second, say, the object will always be found at rest in one position during a certain duration, however short (to find the object in all of its positions the observer should use a camera with an infinite speed: there is reason to think that in reality motion is continuous).

So, during a $1/10^{th}$ of a second, the object is found at rest in A—we call it its actual position, the position which is manifest, which is perceived. But at the instant when it is perceived this position does not exist any more. On the one hand because the light signal the observer receives from the outside world needs some time to reach him (for example a light ray needs some 8 seconds to travel from the Sun to the Earth). And on the other hand because the observer needs about 1/8th of a second to construct a visual image (Turner, 2007). The state of reality he perceives is then past and exists no more when he perceives it. What he sees is not reality but the representation he has created of it and which exists only in his memory.

So, when the observer perceives the object at rest in A, it is no more there, it is somewhere in between A and B and it is possible to tell where only in a probabilistic way: in between A and B it is not perceived, which means that it has no determined, actual positions but only more or less probable positions, which we shall call potential.

But if the object is not perceived between A and B, it is nevertheless present there, it did not suddenly disappear. That it is not perceived does not mean that it ceased to exist in reality, but only that it is not manifest, that it has no spatial position, that it is not in the observer's space.

Where is it then?

When the object travels from actual spatial position A to actual spatial position B, it passes through a succession of intermediary potential positions which are not perceived. If A and B were separated by zero intermediary potential position, they would be one and the same position. In other words, they would be simultaneous, *i.e.* with a zero interval of time between them. The interval of potential positions between them is then a time interval.

It is in this time interval that the object moves from A to B. It is present in reality, but not in the observer's space: it is not manifest, it has neither form nor localization, it is in his time: the object moves not in space, but in time—where it is not perceived.

In the observer's space, the object is always at rest in one determined (actual) position. In his time, it is never at rest and has not one determined position but a plurality of probable (potential) positions.

2. Measurement

Let us now tackle the famous "Measurement problem" in Quantum Mechanics. When a quantum object is not observed it is in a superposition of all its possible states and spatial positions, in accordance with a certain order of probability described by its wavefunction.

But when the object is measured, *i.e.* when it physically interacts with the physicist's observation device, its wavefunction collapses: the plurality of its potential states and positions is suddenly reduced to one actual state and position. In other words, when the quantum object is not observed it is in the observer's time, where it is in a superposition of states and positions. When it is observed, when it physically clashes with the observation device, it enters the observer's space, where it can be in only one state and one position. The "measurement problem" is the passing of the object from the observer's time into his space.

3. Non-Locality

Let us go farther and look at another problem which is may be even more puzzling for physicists: the problem of non-locality. Non-locality is closely related with the measurement problem, it may event be considered an extension of it.

Two particles having interacted are said to be entangled: they have now the same wavefunction and are one system. When one of them is measured, the wavefunction collapses and the other is instantly found in a correlated state, wherever it is in space, even at millions of km.

First it was supposed that the measurement of the first particle acted on the other. But such an "action at a distance" requires time. Yet here, it is instantaneous, regardless of the distance. It would then require a speed higher than the speed of light, which is considered impossible by Relativity. If Relativity is right, there is no "action at a distance".

The important point here is that the entangled particles are in a correlated state after the measurement. Before, they are in a superposition of states and positions. After, the wavefuncion collapses: the particle enters the observer's space, where it is in one determined state and position. Its twin particle is then instantly found in a correlated state, wherever it is in space.

The measurement occurs when the two particles are in the observer's time: as they have one wavefunction, both are equally affected. But when they are in time, they are not in space: there is no distance between them. They enter the observer's space after the act of measurement, as its result, and then they are correlated even if they are a huge distance apart. Hence the amazement of physicists who ask themselves how the second particle could react instantaneously to the measurement of the first, as if there were no distance between them. And indeed, before the measurement there is no distance between them since they are not in the observer's space: there is a distance only after the measurement, when they are spatialized.

If the physicists are puzzled, it is because they implicitly assume that space and time are exterior to the observers, that they exist in objective reality, an idea spontaneously and quasi-unanimously considered as obvious, even if it lacks a demonstration.

Some two centuries ago, Kant was the first to question it. He maintained that space and time are not exterior but interior to the observers, that they are the "a priori forms of sensible intuition", *i.e.* the two dimensions which shape our perception of the world, prior to any experience. We perceive the world in terms of space and time because it is our necessary way of perceving it and we cannot perceive it otherwise. Which means that we do not perceive it as it is but as our mode of perception allows us to perceive it (Kant, 2021).

4. Conclusion

If space and time were part of objective reality, no element of objective reality could be in one without being also in the other so that there would be no passing from the one into the other.

But Quantum Mechanics shows that they are antinomical: in space reality is manifest and local, in time, it is non-manifest and non-local. So no object can be at the same time in both. This is possible only if they are not observer-independent dimensions of objective reality but features of the observer's representation of reality and if they exist only in his consciousness. That is if Kant is right.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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