

Article

Where and How Do They Happen?

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Abstract

This is a two part paper. The first part, written somewhat earlier, presented standard processes which cannot so easily be accommodated within what are presently considered as physical type realms. The second part further elaborates on that fact. In particular, it is argued that quantum superposition and entanglement may better be understood in extensions of what we usually consider as physical type realms, realms which, as it happens, have so far never been defined precisely enough.

Part I

Summary

It has for ages been a rather constant feature of thinking in science to take it for granted that the respective thinking happens in realms which are totally outside and independent of all the other phenomena that constitute the objects of such thinking. The imposition of this divide on two levels may conflict with basic assumptions of Newtonian and Einsteinian mechanics, as well as with those in Quantum Mechanics. It also raises the question whether the realms in which thinking happens have no any other connection with the realms science deals with, except to host and allow scientific thinking.

0. The Yet Undefined Physical Realms ...

In the sequel, based on rather obvious and simple, even if so far seldom considered facts within, or related to Physics, we shall argue that what are usually assumed to be the Physical Realms may have to be extended. Such possible additional realms, however, are not along those infinitely many of Everett's "many-worlds" view of Quantum Mechanics. Instead, they are suggesting a finite number of further physical type realms, thus they can be seen as a development of the classical Cartesian realm of "res extensa".

As for what Physical Realms may actually mean, or rather, Physics itself, here is a recent and quite appropriate view on that never yet clarified issue, [8, pp. 153,154] :

"Physics is the study of those phenomena that are successfully treatable with well-specified and testable models.

For example, Physics treats atoms and simple molecules. Chemistry, on the other hand, deals with all molecules, most of whose electron distributions cannot be well specified. A physicist might study a well specified biological system, but the functioning of a complex organism lies in the domain of biologists.

Anything not successfully treatable with a well-specified and testable model is rather quickly defined out of Physics."

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It is quite clear in this spirit that, even if no one seems to care much about a more precise definition of Physics, and thus, of Physical Realms, phenomena such as human thinking, let alone, human consciousness or awareness, are not expected to concern Physics any time soon. Consequently, what for Descartes constituted "res cogitans", that is, the realms of thinking, are supposed to remain in the splendour of their undisturbed solitude, as far as Physics is concerned. And then, anything that may be seen as remotely acceptable from a physical point of view, may be but a refinement, or rather, a structural enrichment of the Cartesian "res extensa", that is, of the realms which, at least intuitively, are supposed to have to do with Physics.

And yet, as seen in the sequel, the story is not quite that simple, not even from a strictly physical point of view ...

1. Conflict with Newtonian Mechanics

Instant action at arbitrary distance, such as in the case of gravitation, is one of the basic assumptions of Newtonian mechanics. This certainly does not appear to conflict with the fact that we can think instantly and simultaneously about phenomena which are no matter how far apart from one another in space or in time. However, absolute space is also a basic assumption of Newtonian Mechanics. And it is supposed to contain absolutely everything that may exist in Creation, be it in the past, present or future. Consequently, it is supposed to contain, among others, the physical body of the thinking scientist as well.

Yet it is not equally clear whether it also contains scientific thinking itself which, traditionally, is assumed to be totally outside and independent of all phenomena under its consideration, therefore in particular, of the Newtonian absolute space, and also, of absolute time.

And then the question arises :

Where and how does such a scientific thinking take place or happen ?

2. A difference with Mathematics

Mathematical thinking, especially in its modern and abstract variants, does not appear to need the assumption of any absolute space, or for that matter, absolute time. Such thinking may appear to unfold during appropriate local time intervals. However, when seen all in itself, and unrelated to the physical body of the respective mathematician, it is quite likely that such thinking has no location in any space, be it relative or absolute.

3. Conflict with Einsteinian Mechanics

In Einsteinian Mechanics a basic assumption is that there cannot be any propagation of action faster than light.

Yet just like in the case we happen to think in terms of Newtonian Mechanics, our thinking in terms of Einsteinian Mechanics can again instantly and simultaneously be about phenomena no matter how far apart from one another in space or time.

Consequently, the question arises :

Given the mentioned relativistic limitation, how and where does such a thinking happen ?

4. Conflict with Quantum Mechanics

Let us consider the classical EPR, or Einstein-Podolsky-Rosen entanglement phenomenon, and for simplicity, do so in the terms of quantum computation. For that purpose it suffices to consider double qubits, that is, elements of $\mathbb{C}^2 \otimes \mathbb{C}^2$, such as for instance the EPR pair

$$(4.1) \quad \begin{aligned} |\omega_{00}\rangle &= |0,0\rangle + |1,1\rangle = \\ &= |0\rangle \otimes |0\rangle + |1\rangle \otimes |1\rangle \in \mathbb{C}^2 \otimes \mathbb{C}^2 \end{aligned}$$

which is well known to be *entangled*, in other words, $|\omega_{00}\rangle$ is *not* of the form

$$(\alpha|0\rangle + \beta|1\rangle) \otimes (\gamma|0\rangle + \delta|1\rangle) \in \mathbb{C}^2 \otimes \mathbb{C}^2$$

for any $\alpha, \beta, \gamma, \delta \in \mathbb{C}^2$.

Here we can turn to the usual and rather picturesque description used in quantum computation, where two fictitious personages, Alice and Bob, are supposed to exchange information, be it of classical or quantum type.

Alice and Bob can each take their respective qubit from the entangled, or EPR pair of qubits $|\omega_{00}\rangle$, and then go away with it no matter how far apart from one another. And the two qubits thus separated in space will remain entangled, unless of course one or both of them get involved in further classical or quantum interactions. For clarity, however, we should note that the single qubits which, respectively, Alice and Bob take away with them from the EPR pair $|\omega_{00}\rangle$ are neither one of the terms $|0,0\rangle$ or $|1,1\rangle$ in (4.1), since both these are themselves already pairs of qubits, thus they cannot be taken away as mere single qubits, either by Alice, or by Bob. Consequently, the single qubits which Alice and Bob take away with them cannot be described in any other form, except that which is implicit in (4.1).

Now, after that short detour into the language of quantum computation, we can note that, according to Quantum Mechanics, the entanglement in the EPR double qubit $|\omega_{00}\rangle$ implies that the states of the two qubits which compose it are correlated, no matter how far from one another Alice and Bob would be with them. Consequently, knowing the state of one of these two qubits can give information about the state of the other qubit. On the other hand, in view of General, or even Special Relativity, such a knowledge, say by Alice, cannot be communicated to Bob faster than the velocity of light.

And yet, anybody who is familiar enough with Quantum Mechanics, can instantly know and understand all of the above, no matter how far away from one another Alice and Bob may be with their respective single but entangled qubits.

So that, again, the question arises :

How and where does such a thinking happen ?

5. Two, Among Other Possible Alternatives

Let us first assume that scientific thinking does indeed happen in realms outside and independent of all the realms in which the variety of phenomena studied by scientific thinking takes place. Then the very existence of scientific thinking proves the existence of realms transcendental to those which at present are customarily the object of that scientific thinking.

In this case, one may ask whether the realms in which scientific thinking happens have, indeed, no any

other connection whatsoever with the realms which are the object of study of science, except to host and allow such scientific thinking.

A cautious answer is of course not one of categorical negation. Furthermore, any answer, including a categorically negative one, may need some supporting evidence, and possibly of experimental or empirical kind as well.

If alternatively, we assume that, after all, there is only one overall realm in which everything happens, then quite likely we may have to extend rather significantly, if not in fact dramatically, the list of entities, phenomena, or processes which are, or can be relevant in Physics, Chemistry, Biology, and so on. Certainly, in such a case it can no longer be taken for granted - and done so without any supporting evidence - that the whole range of entities and their interactions which form the object of science are isolated in some subdomain of that unique overall realm. And very much isolated they appear to be, since usual scientific thinking itself is assumed to be outside and independent of them, plus we deal with all those entities and their interactions as if they were perfectly self-contained.

6. Conclusions

It may be useful to ask the following four questions :

1. Do we believe that whatever in Creation which may be relevant to science is already accessible to our awareness ?
2. And if not - which is most likely the case - then do we believe that it may become accessible during the lifetime of our own generation ?
3. And if not - which again is most likely the case - then do we believe that we should nevertheless try some sort of two way interactions with all that which may never ever become accessible to the awareness of our generation, yet may nevertheless be relevant to science even in our own days ?
4. And if yes - which most likely is the minimally wise approach - then how do we intend to get into a two way interaction with all those realms about which our only awareness can be that they shall never ever be within our awareness, or perhaps, not even of human awareness as such, no matter how long our species may live ?

Part II

Summary

It is further argued that quantum superposition and entanglement may better be understood in extensions of what we usually consider to be physical type realms, realms which in fact have never been defined precisely enough.

1. Superposition : a Typically Quantum Fundamental Phenomenon

In the non-relativistic Quantum Mechanics of a finite system S described by states in a Hilbert space H , if for instance $\psi_1, \psi_2 \in H$ are two possible orthogonal states of the system S , then further states of S are given by the arbitrary linear combinations

$$(1.1) \quad \psi = c_1\psi_1 + c_2\psi_2, \quad c_1, c_2 \in \mathbb{C}$$

where the usual normalizing conditions are assumed

$$(1.2) \quad \|\psi_1\| = \|\psi_2\| = 1, \quad |c_1|^2 + |c_2|^2 = 1$$

hence resulting as well in

$$(1.3) \quad \|\psi\| = 1$$

So far, in no other theory of Physics is such a property present. As for the importance of that property in Quantum Mechanics it suffices to recall two facts : it leads to yet unsolved foundational controversies, as in the celebrated argument in Schrödinger's Cat, and it is considered to be one of the basic resources of quantum computers, a resource which allows them unprecedented computational power, a power not possible to attain with usual electronic computers.

2. Realms Physical, and Other Ones Less So ?

It is nowadays a fundamental assumption that the Physical Realms do surely contain all there is, or at least, all there is of interest to Physics. And as with many a fundamental assumption, this one is so deeply ingrained that hardly anyone finds any reason at all to make it explicit to any extent.

One of the amusing aspects of such an approach is the convenient *circularity* of the argument, a circularity which, however, does not seem to concern in the least its proponents ...

Another amusing aspect is the recently emerging credo, according to which "information is physical" ... This credo does, of course, reflect an awareness that what earlier were perceived, mostly tacitly, as the possible boundaries of the Physical Realms should now be extended in order not to leave out such an entity of fast growing importance like information.

And needless to say, such a move to encompass information within the Physical Realms is rather easy to accomplish, since the latter remains as undefined as it has always been ...

Indeed, there is here a significant mismatch between the rather clear definition of information in present day science and technology, and on the other hand, the actual, and quite convenient vagueness of what the Physical Realms are supposed to be about. Not to mention that, in spite of the insistent propagation of that newly emerged credo, the concept of information is in fact treated as a second class one at best in most of the present day fundamental theories of Physics, including in Quantum Mechanics.

On the other hand, and despite of the above, it is quite clear that the so called Physical Realms, even in their ever vague and latest extended sense, do *not* contain all that is of interest. And on top of it, they happen to *fail* to do so precisely on their own terms.

Several such instances were discussed in Part I, and here we recall one of them :

Anybody, and even more so a physicist, can at the same time think about two arbitrarily far away places in the universe, for instance, two galaxies.

On the other hand, according to Relativity Theory, no physical interaction can take place

with arbitrary velocity.

Thus such a thinking, so easily and so commonly available to quite everybody, *cannot* be of a physical nature.

And then, the question arises :

Where and how does such a thinking happen, if not within the Physical Realms, and definitely not there, in view of Physics itself ?

And while such a question remains unanswered, and in fact, not even considered by present day Physics, perhaps one may as well compound the issue with the following.

It was Descartes in the early 1600s, who suggested the existence of two distinct realms. His "res extensa" was more or less what has been meant by the Physical Realms. On the other hand, his "res cogitans" was a realm beyond and outside of "res extensa", and it encompassed thinking.

As a consequence, Descartes has for long been ridiculed as being a dualist ...

Such a judgment misses, however, the fundamental fact that, as so many major European scientists of his time, Descartes himself was a deeply religious person in the Christian tradition. Consequently, he could not possibly be less removed from dualism than anybody else, since he saw God as underlying all Creation, and thus in particular, both "res extensa" and "res cogitans".

Now of course, Descartes himself did not advocate the study of "res cogitans" by the means of Physics, whatever the latter may mean under reasonable conditions.

And Classical Physics, that is, prior to the 20th century, did not in any way seem to require a more direct involvement of "res cogitans" than it would usually happen in the customary thinking process of normal humans, among them, physicists.

Relativity Theory, in spite of the above question, has not changed that classical situation, and it did not appear to need to do so. What it does instead, and even if not yet seriously considered, is to point quite sharply to the existence of at least two very different realms. And for the lack of better terms, as well as a homage to Descartes, we can still call those two realms as "res extensa" and "res cogitans", respectively.

3. Does Superposition Need a Third Realm ?

This may not be such an easy to answer question as one would like it. Indeed, Schrödinger's Cat already shows that it is not trivial. Therefore, let us consider it with some care.

What is obvious from (1.1) - (1.3) is that superposition takes place in the Hilbert space H , that is, within the mathematical model of the quantum system S . And as mathematical models go, they may hopefully reflect their respective system which, of course, is supposed to be situated in "res extensa", but on the other hand, as mere models, are *not* supposed to be identical with such a system.

This failure to distinguish between a physical system and its model is precisely one of the reasons one ends up with the controversy about Schrödinger's Cat.

And then, the question arises :

Are superpositions (1.1) - (1.3) bona fide physical phenomena, or on the contrary, they are merely convenient features of the respective mathematical model ?

Well, as far as one can understand, this question does not have a clear enough answer in present day Quantum Mechanics.

However, as it may happen with not a few physicists, in case one tends to consider superpositions as genuine physical phenomena, then the foundational controversy around Schrödinger's Cat may simply be set aside by considering a *third* realm which we may call "res super-extensa", and in which such superpositions take place. This realm contains the usual "res extensa", in the sense that ψ in (1.1), as a superposition of ψ_1 and ψ_2 , belongs to it, without however belonging to "res extensa", while ψ_1 and ψ_2 belong to the latter. Clearly, just as with "res extensa", there is no need for any overlapping between "res super-extensa" and "res cogitans".

Here, however, one should note that the mathematical model (1.1) - (1.3), assumed to be in "res cogitans", need not always distinguish between "res extensa" and "res super-extensa". Indeed, ψ in (1.1), as an element of the Hilbert space H , can in itself belong to "res extensa", as long as it is not seen as being constituted as a superposition.

The point to note with the above is that it is precisely the preference to see superpositions as physically real, that is, as having genuine physical existence, and not merely being representations in a mathematical model, which, when considered together with conundrums such as Schrödinger's Cat, can suggest the consideration of a third realm, such as that of "res super-extensa".

4. And How About Entanglements ?

As seen in Part I, entanglement also raises a question as to where and how it happens, given what appears to be its instantaneous nonlocal manifestation.

And yet, it may appear that entanglement, even more than superposition, is seen by physicists as a genuine physical phenomenon, and not merely as some occurrence in the mathematical model. In this regard, no less than superpositions, entanglements are typical quantum phenomena, as well as unprecedented resources in quantum computation. As for their foundational importance, it suffices to recall the celebrated EPR paper, with all the related subsequent developments.

Thus a fundamental and still controversial issue which entanglements bring up is that of *nonlocality*. This fact, as is well known, was brought forward most starkly with the celebrated Bell Inequalities.

Here however, once one may consider the possibility of a third realm, like for instance, the above "res super-extensa", which is in fact but a *larger* instance of the customary "res extensa", the very issue of nonlocality may benefit from a new view and understanding. Indeed, it may simply happen that in "res super-extensa" the dichotomy "local - nonlocal" is meaningless. And here we should recall that such a possibility is not at all strange, since in a bounded system modelled mathematically by a compact space, the very concept of "nonlocal" loses much of its usual difficulties, if not in fact, its meaning. And in this regard we can recall that, so far, the very question whether the whole of the universe itself is in fact bounded is still open.

But then, and as if to complicate the issues, entanglements need *not* necessarily happen in the same extension of "res extensa" in which superposition may happen. Consequently, we may yet have to consider another, namely, third physical type realm as well.

A further possible consequence of considering physical extensions of the usual "res extensa" is that the foundational controversy related to the so called "hidden variables" in Quantum Mechanics may give

way in favour of whole physical realms which, so far, were themselves hidden. In other words, it may well happen that what has been missing were not some hidden variables within this or that quantum entity, but rather whole physical type *realms* within which the very quantum processes as a whole may actually take place.

And with the acceptance in String Theory of the fact that the so called Physical Realms may have highly counterintuitive large finite dimensions, some of them so contracted as to make the dichotomy "local - nonlocal" quite meaningless, there is no longer any particular reason to be so parsimonious when considering the possible realms, beyond the usual "res extensa", that may be relevant to Physics.

5. Conclusions

Several extensions of what usually is meant by the otherwise undefined concept of Physical Realms were argued, based on rather obvious, simple, as well as fundamental physical considerations. In section 2, such an extension is motivated by the limitation of velocity of physical interactions, as follows from Relativity. In section 3, it was argued that, precisely to the extent that quantum superposition is not a mere feature of a mathematical model, but a genuine physical phenomenon, an extension of the customary concept of Physical Realms may be needed. In section 4, it was argued that quantum entanglement may need yet another such extension.

And as suggested, such possible extensions of the concept of Physical Realms need not necessarily be given by one and the same additional realm.

In case such a multiplicity of realms, beyond the two classical Cartesian ones, may raise certain concerns, one can always remember that, as thinking humans, thus in particular, physicists, our basic realm is in fact the "res cogitans". No wonder that Descartes insisted on what he considered as the fundamental ontological fact for us humans, namely, "cogito, ergo sum" ...

And therefore, without much further intellectual effort, we may at a certain stage subsume all other possible realms to that one. In other words, we may as well consider that everything is but a model, including what for so long we considered as having "objective" existence, whatever "objective" may happen to mean, namely, the Physical Realms.

The only major difference such a subsumation may imply is that we should redefine accordingly what we mean by "experimental evidence", and in particular, by "falsifiability".

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