Opinion and Perspectives

The Existence and Role of Quantum-state Noise

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Abstract

The key observation about the quantum reality is that it looks as if there is a moment when the probability of a quantum event becomes reality for us. However, after careful analysis, it looks plausible that what we believe is a definite state in our reality, observed as an outcome of a quantum experiment, is actually not a definite state. From there, we conclude that the quantum world is an active world whose influence lies beyond the statistical and permanent determination of reality as we know it.

Key Words: reality concept, quantum state, physical laws, question of choice, measuring process, origin of laws

NeuroQuantology 2010; 4: 626-632

Introduction

The overall picture presented here will assume three things:

1. No observable state can reduce its probability to 0 or advance it to 1 - it can only have the probability of 1 or 0 all the time.

2. A completely isolated quantum system does not exist. However, it is possible to reduce or have reduced the effect of the environment for particular variables or attributes in the system. We can speak only about relatively isolated systems.

3. When two or more relatively isolated quantum systems interact we obtain new combined states. If we decrease the probability of interaction, we can extract the initial systems.

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Received: July 31, 2010 ; Revised: September 25, 2010; Accepted: Sept 28, 2010.

1. No zero probability

We try to understand quantum reality by freezing one or several fixed outcomes with the aggregate probability close to 1, because the experience is teaching us that we always distinguish certain outcomes. However, in reality, we rely on our experience, which means that we cannot make any difference between the probability 1 and a probability of, for example, $1\text{-}10^{-3000}$, because we do not have time to wait and observe the complementary event that has so small probability as 10^{-3000}. If an event has an extremely small probability, it might not even happen since the Universe was born, but it still does not mean it is impossible, i.e. that its probability is 0. This fact simply means that ψ function, *wave function* (Bohm, 1989), never collapses (Lundeen, 2009). It is the experience that forces us to believe that it does. There is no frozen reality, frozen past as such. Everything that was possible is possible and will always be possible.

We could say the same in a different way. If an event has probability 1, it cannot reduce this probability. It means that an event with probability 1 has never happened;

it is simply a constant truth. On the other hand, if an event has probability 0, it did not happen and could never happen.

2. No isolation

If two systems could live in isolation, it would mean that the probability of combining their ψ functions has to be 0. However, observable events with probability 0 do not exist in any system. Therefore, if these two systems can potentially interact, there is always a possibility of their interaction, so they do interact to some, however small, extent.

Still, if we do imagine two systems in constant isolation, then we assume they will never interact, but, in that case, we cannot find an observer who would be able even to count them. (Imagine we are able to observe the systems. Then, the observer's quantum system would be a connection between two systems through which they would be able to interact. However, the systems are isolated, so no form of interaction exists. That means we would not be able to talk about *two* isolated systems in the first place.)

3. Interaction

Only by decreasing or increasing the probability of interaction, we can separate or connect two or more systems. Two or more systems are always combined. In essence, the entire Universe is one quantum system and each part depends on another part and affects it, in some measure, instantly.

Measuring process

If we take all the above into account, a measuring process could be understood as forcing the entire Universe to display one of its current attributes, and in every moment it will display one value based on the current ψ function of the Universe. However, other possible values will not vanish. By measuring, we do not exclude other values; just reduce their visibility and perceptibility.

When we measure something, we "ask" the Universe to "answer" which value of attributes in question is more probable at that moment. And we get the answer back. Thus, if we had two states, A and B, both with a probability of, for example, 1/2, after the measuring process, we have two corresponding states: A, with probability, for example, $1\text{-}10^{-3000}$, and B, with the complementary probability of 10^{-3000}. Following the experiment, we cannot really observe state B anymore, and for quite a long time, because it has so little probability, yet it does not mean it did disappear or vanish. For us, the probability of $1\text{-}10^{-3000}$ is the same as 1, because whenever we combine our quantum world, us, with the system that has a state with probability $1\text{-}10^{-3000}$, this state is the only one discernible. We cannot (and really do not want to) spot any influence of any other far less useful state, and that is happening repeatedly for a very long time, and whenever and wherever we observe the system. From this experience, we have no reason to believe that other states did not really vanish, although they did not. All states always react with our own ψ function, and then with our eyes, brain, ... when a chain of chemical reactions confirms that the state with probability $1\text{-}10^{-3000}$ is the most probable and useful state in the system. Only then, we deduce that this is doubtlessly a single existing state, because that one state is the only state that can induce a sequence of needed specific global actions in our short lifetime and on this planet; at least far more effectively than the event with probability 10^{-3000}.

The question is why we had the probabilities 1/2 and 1/2, and now we have $1\text{-}10^{-3000}$ and 10^{-3000}. The answer lies in the measuring process itself. We introduced the apparatus with its own ψ function, the function that is far more robust, strict, precise and defined than the one of the system in observation. We obviously forced the system to combine and merge with the apparatus in order to display certain value or values. After the measuring process, we do not have the system in observation any longer. Instead, we have only a combination of the measuring apparatus and the system. However, the measuring device is constructed in such a way that it cannot observably stay in several states at the same time, the way the system can. It is constructed exactly to boost one or a couple of specific values. By measuring, we do not ask how the system is behaving. We are asking far more how the device behaves under the influence of the observed system - and then we deduce the system's behavior. And together with an apparatus, we introduce ourselves, with our mass, system, thoughts, experience, past, expectations, actions...

By creating a measuring device for a particular attribute, we have reduced the future probability of the about-to-be measured attribute being in several states as much as we could or wanted. That is exactly the result we obtained in the end: a reduced set of different probabilities. Nothing happened either with the observed system or with the measuring device. They have just merged. What we wanted with our measuring device as well is to create a record, something lasting, i.e. to extract strictly one state and somehow use the actuality later to combine the system with other systems in order to create a predictable reality. Therefore, the final probabilities are not those of the observed system, but much more of the apparatus. If we measured the states A and B, and the apparatus has had only two possible final states: A being close to 1, and B to 0, that is exactly what we obtained in the end.

Now, let us imagine a standard experiment (a simplified version of a quantum eraser experiment) with a photon and half-silvered mirrors where we have an additional quantum barrier that can quickly appear and disappear. If this periodic barrier appears when a photon is sent, but disappears only a moment before the photon could reach another half-transparent mirror at the exit, we would not even notice that any barrier ever existed. However, if you take that a periodic barrier was a device, it would detect a photon, taken locally, in about half of all attempts (although we would not be able to participate in any particular measurement). It should detect a photon, because the barrier was there and combined itself with the photon. It has been removed only a moment before the photon would reach the exit. Obviously, although a barrier should, by our understanding, collapse the ψ function, because it either detected or did not detect the photon, it would not do that. Everything happens as if a barrier does not exist. That means that the probability of a barrier detecting a photon is never in total either 1 or 0, it can be only very close to that. ψ function never collapses.

If we would know how to dismantle all of used measuring devices in such a way that, on the quantum level, they do not exist any longer (which is the same as saying 'if we would be able to revert the ψ function that created them'), we would have the measured system back to exactly what it would be if the measuring process never happened.

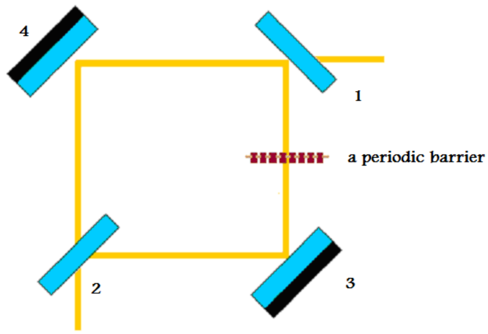

Figure 1. A version of a standard quantum eraser experiment with two beam splitters (or half-silvered mirrors) with a periodic barrier on one of the photon's paths. If we remove the barrier just before a photon reaches another splitter, but not before the photon could reach the barrier, we would not notice that the barrier was ever active. Nevertheless, the barrier, taken locally, should sometimes detect the photon when it should collapse its ψ function. We should notice that collapse if it were irreversible. (1 and 2 are beam splitters; 3 and 4 are normal mirrors.)

Together with a device, we include ourselves in the examination; and we definitely do not know how to revert our own ψ function. Assume we have reverted it somehow. Unfortunately, this would require returning to ignorance about the system that we measured, because our knowledge is based only on our experience, memories and observations about the system.

Quantum-state noise

The observation about the *wave function* that never collapses says that no information about the system is ever lost (Braunstein, 2007). We can retrieve from the system all previously highly probable states, and the others, either by reverting ψ or by finding a method of increasing the probability of states with minute chance. It is as if we turned down the volume of music, but nothing is lost in the process, because if we find a method to make it louder, we will hear it again in its entirety.

Mathematically speaking, if we describe a *wave function* ψ through a combination of orthogonal states S = $\{\phi_0, \phi_1, \phi_2, \phi_3, \ldots\}$

$$\left|\psi\right\rangle = \sum_i c_i \left|\phi_i\right\rangle \quad \left\langle\phi_i\middle|\phi_j\right\rangle = \delta_{ij} \qquad (1)$$

we say that throughout the entire history of the system:

1. either $\phi_i \in S$ or $\phi_i \notin S$ - the system knows all its states, a state cannot be added or removed

2. $c_i=0$ if and only if $\phi_i \notin S$ - the system cannot forget any of its states

As usual, we can agree that probability p_i of state ϕ_i is equal to $|c_i|^2$. Because we said that there is only one quantum system, which is the entire Universe, we can extract separate quantum systems by temporarily reducing the probability of those states we would like to exclude from our observation.

Let us assume there is a measure p_w of a cutoff probability of observation (which is the probability that a state is detectable within certain limits). If we would be able to reduce p_w as much as we want, all states ϕ_i that have $|c_i|^2 \leq p_w$ would start being less and less detectable for us. The fact that we cannot detect any of them does not mean that p_w automatically becomes 0 - it never does.

A measuring process equals reducing p_w and c_i's, at first in the device, so low that only a few states of interest remain detectable within the given limits (period of time and space), then combining the device with the tested system so that all the states, except one, have got $|c_i|^2 \leq p_w$ (i.e. have got a very low probability of being detected). Because only one is reaching a probability sufficiently close to 1, we cannot notice any other possible events within the given limits. Besides, even after the measuring process has finished, *we* are actively reducing the probability of the other possible but unnoticed events. This last one is the real reason we commonly believe that all other outcomes, save the one our apparatus or experience has shown, are not possible any longer - because we are *actively* reducing their probabilities.

The general problem here is not the fact that we currently approximate probabilities close to 1 with 1 and those close to 0 with 0, because we want to deal with observable parts of the Universe where a small probability event is imperceptible, so, for us, irrelevant. (For this reason, we approximate almost everything in quantum theory; we have no other choice.) The problem is in the reduction of the number of states in a system.

When we exclude any state from the system, we forbid its interaction with other states and other systems, but we cannot claim that events with a very little probability have no influence because they are not interesting for us. We do not know how these minuscule events affect our reality and other quantum systems. We will mention two known phenomena where a small influence can have an important if not the crucial final role:

1. *Chaos theory*: a small event in a chaotic system can ignite a disproportionately large effect (Falconer, 2003; Berry, 2010)

2. *Statistical theory*: noise within a distribution, which can be mathematically almost ignored or disregarded, has the crucial dynamic role in shaping the final distribution measure of the system (Freedman, 2009)

If nothing else, we cannot fully understand the dynamics of a system if some of its apparently unimportant states are suddenly excluded. Besides the dynamics, the geometry of space could be equally important. Imagine, we have a die with six sides and one side, for example 6, is so heavy (made of neutron star if you like, but only that one side, the others are of wood) that it regularly falls on 6. If we observe the outcome, it is now so constantly 1 (assuming 6 and 1 are on the opposite sides) that we have no reason to believe it is not always 1. However, if we ignore other five sides, we might never understand the cubic shape of the die.

At the moment, in every system, we disregard the sum of states whose combined probability lies beyond perceptible or measurable reality using our current technology - *the quantum-state noise*. Disregarding it is not a problem, but what we additionally believe is that this noise is mute. It is not.

The key point of this entire essay is that *a quantum system remains quantum even beyond any measurement or observation*.

Gravity as an example

If we understand the above experiment, we might continue by asking questions about gravity and other obvious laws that are, for us, firmly established truths with so abundant evidence in the Universe. They must have probability 1, don't they? If the gravity is an established truth, it has probability 1. In that sense, it is a principle, and if another universe exists, and it has gravity, it certainly has the same form of gravity as we do.

Let us analyze the other possibility, and that is that gravity (here, gravity is taken as a general illustration of *any* possible force or attribute) is not a fundamental eternal truth. If so, then the gravity had appeared at one point in time with the features we can observe today. Before that, all other forms of gravity were possible. (These forms we cannot discuss, since we do not know what forms gravity could have, but we can take a simple imaginative example of gravity being reversed, instead of an attraction force to be a repulsive one, assuming that both were possible.)

Following our discussion, it seems that although we can observe one form of gravity, other forms are, however unlikely or unobservable, still possible. Now, the question is why we can observe so dominantly only this attraction-based version of gravity. The reason is actually very simple. Planets, stars, galaxies, clusters of galaxies and other even larger and more powerful known or unknown gravitational forms behave like measuring equipment. Their constant interaction is what keeps this attractive version of gravity with that high probability for us. Additionally, we are part of that system, since our body is created from these same stars. We are part of that "attractive gravity" system and we interact with that system the same way they interact with each other - we are pulled down all the time.

This does not mean that the other forms of gravity cannot coexist somewhere on its own with high probability. A certain part of the Universe may repulse (our attractive version would have a low probability there), and we might even be able to detect its effect. However, it would be very difficult to use our current methodologies and study that form of gravity, because we would have to mix our form of gravity, which is highly probable in our galaxy, with a specific form of gravity that definitely could not engulf our world noticeably. We would not be able to become a quantum part of that form of gravity without destruction. The experiments related to other forms of gravity will be either very small, require an extreme amount of energy or remain observed from far distance based on discernible cosmic effects. It is to expect that such parts of the Universe would be mostly dark to us; even more if other attributes and forces are equally intangible there.

The question of what makes this attractive form of gravity we experience so abundant answers itself: it is its ability to be an abundant and long-lasting force.

Is it possible to miss detecting other versions of gravity (not to forget that gravity is just an example here)? Yes, because it is possible two systems with the same version of gravity to interact even when a system of another type of gravity is between them.

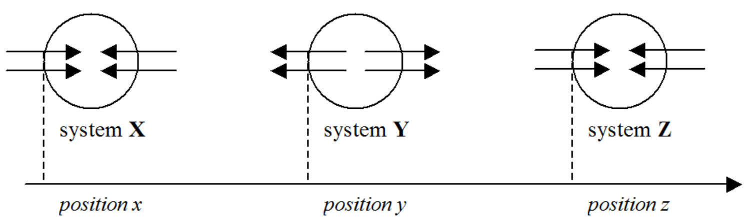

Figure 2. Systems X and Z have the attractive version of gravity, and Y has an imaginative repulsive one. The interaction between two compatible and sustainable systems, X and Z, does not have to be affected by any incompatible system Y that stands in-between.

If we have two systems, X and Z, with the attractive gravitational force, separated by system Y that has a repulsive force, (and this does not allow the attractive force to be noticeable in system Y), X and Z can still interact. Depending on the nature of the repulsive force, system Y might not have any influence on X or Z, only on the systems similar to Y that have the repulsive force active. The opposite could be equally true: Y could interact with X and Z, but even then Y is still not an obstacle for X and Z to interact. For example, if Y does affect X and Z, it is sufficient the repulsive force of Y to be of shorter range than the attractive force of X and Z etc.

Two systems, like X and Z, could interact even though the gravity became an attractive force in X and in Z independently, simply because it was one of the versions of gravity they could choose from the start.

If we have, for example, 10 different long-lasting versions of gravity, any system on its own, with as small as possible influence of other systems in the Universe, would develop one of these versions of gravity in the end. This would allow interaction with other similar and trackable systems, although the system had nothing in common with them at first.

As we mentioned earlier, similar to gravity, there are other attributes we can analyze using the same line of arguments, like the direction of time flow, the speed of light...

Physical laws

What we are saying here is that this same Universe is capable of displaying those peculiarities on the quantum level as many big relatively separate parts where each quantum inconsistency becomes consistent on its own on a large scale. All these parts would still be distant, either in time or space, so as not to have to combine strongly or coexist with other apparent quantum inconsistencies. What is for us a combined puzzling observation on the quantum level could be multiplied and developed as a separate reality on a grand cosmic scale.

Is this ruining the picture of constant laws of physics throughout the Universe?

Yes and No.

Yes - because what we can observe and deduce is this way or another just a limited version of possible laws, something that maybe cannot be ascribed to the entire Universe, however abundant it may look to us. We might never be able to establish the connection to other parts of the Universe with other laws that describe a different behavior. Some laws we cherish might be, not invalid, but inapplicable to other parts of the Universe. (To be very precise, when we say 'different laws', we imply that we are able to confirm two essentially different patterns in the Universe while we cannot find a limited and relatively large area displaying both at the same time, except on the quantum level.) It means that what we are able to learn here and now is what applies only to our world, but in this same Universe, aliens might have very different laws based on their world and experience. We could try to share our experience with them, but we would need probably an extreme amount of time to understand each other, because we would not be able to match their experience with anything we know or have.

Yes - because there are no universal laws, as we believe today. Laws in other parts of the Universe can be combined in consistent, but for us either unobservable or apparently impossible ways. If we continue analyzing our reality the way we do, we have to admit the limitations and to understand that other forms of laws are possible, forms that we cannot even predict because they would have a very low probability in our world. In order to understand each possible version of law, we would need an extremely profound knowledge, but knowing how difficult it is to examine even our own reality confirms that such a task is an infeasible endeavor.

No - because even in that other part of the Universe the laws are formed based on the local principles. Even though they are different from ours, they share the same feature that their probability, or the probability of their interaction, is very high. That fact must have a reason, some sort of explanation. Therefore, it is possible to understand them, to find a ground for existence of this new combination. However, it is probable that, even if we would understand that reality, we would not be able to use it on a large scale in our world. For example, it is unlikely that we could produce that much energy to annul gravity on any larger scale, because that would require fighting back all huge gravitational interactions crossed on our planet alone. Nevertheless, on a small scale, miracles (from our common expectations) are still possible.

Anyway, we would have to bring our description of laws to a more abstract and general level in order to understand the situation in other parts of the Universe. This could be the reason why we frequently turn to mathematics, which epitomizes much stronger and deeper truths and enduring relations in our Universe or beyond.

In any case, by this observation, we would have to redefine what laws of physics really are:

The physical laws are a consistent and observable set of rules that together can form a relatively large and long-lasting sustainable system.

It is likely that our combination of rules, expressed in the form of physical laws, is not the ultimate, best and the most advanced combination in the Universe, but it could be the only one that the life as we know it is possible.

It is not unlikely either that our set of laws is, for some reason, unique and dominant. Even then, the understanding of how the set of laws has been formed and held together is unraveled if another set of laws somewhere in this same Universe may exist, even if such an area passes unnoticed.

Conclusions

1. The current understanding that matter always only bears and suffers physical laws is partially true. Matter can shape, carry and define physical laws by its interaction. If a physical law has a very high probability, quite close to 1, it is, for us, close to being a principle, although it might not be.

2. A physical law might not be relevant or even definable, apart from being an option, in as vacuous as possible space and beyond the Universe creation.

3. Only a principle can have probability equal to 1. A principle never came into existence; it is always true. Some physical laws came into existence and are shaped by interactions within the Universe. A principle exists in as vacuous as possible space and even beyond the creation of the Universe.

4. Different and separate parts of the Universe may choose the same set of laws independently and start mutual interaction based on this choice.

5. The system cannot forget any of its states. The *wave function* never collapses in such a way that any of its states is suddenly and completely lost. Some states can have a probability very close to 0 or very close to 1, but never *change* the probability either to 1 or 0.

6. Information cannot be completely hidden, even on the quantum level. Any information can be retrieved from the system, although if the probability of an event is very low, it might be an infeasible task, unless we create a device that can quickly enhance the small probability.

7. A quantum system remains quantum even after any measurement or observation occurs.

8. From all said above, the quantum level of reality does not only statistically and firmly shape larger systems. The quantum level is an active level of existence, and we should expect both physically and biologically active processes that shape their surrounding in yet to be discovered ways even on this level.

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