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 a probability of a quantum event or events 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 or experiments, is actually not a definite state. From there, we conclude that quantum world is an active world whose influence lies beyond 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, interpretations

Introduction
The overall picture presented here will assume three things:

1. No observable state can reduce its probability to 0 or advance to 1 - it can only have the probability of 1 or 0 all the time.
2. A completely isolated quantum system as such does not exist, but 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, they interact and we obtain new combined states. If we decrease the probability of interaction, we can extract the initial systems.

1. No zero probability
It is the fact that we try to understand quantum reality by freezing only one or several fixed outcomes with probability 1, because our experience is teaching us that it is always one outcome that we distinguish. However, in reality we rely on our experience, which means that we can't make difference between the probability of 1 and probability of, for example, $1 \times 10^{-3000}$, because we do not have time to wait and observe an 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 that it is impossible, i.e. that its probability is 0. This fact simply means that $\psi$ function (wavefunction) [Bohm] never collapses. It is our 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 another way. If an event has the probability 1, it could never reduce its probability. It means that an event with probability 1 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 can live in isolation, that would mean that the probability of combining their two $\psi$ functions has to be 0, but in no system there is an observable event with probability 0 as such. So if these two systems can potentially interact, there is always possibility of their interaction, so they do interact always to certain, however small, extent. However, if we do imagine two systems in constant isolation, then we conclude that they will never interact, but in that case there is no observer who could ever be able even to count them, because in case we can observe the systems, observer's quantum system would be a connection between two systems through which they would be able to interact, so we could not speak about two isolated systems at first place.

3. Interaction
It is only by decreasing or increasing the probability of interaction how 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 of it depends on another part and affects it at certain level instantly.

Measuring process
If we take all the above, the measuring process could be understood as forcing the entire Universe to display one or another of its current attributes, and of course in every
moment it will display one or another value based on the current $\psi$ function of the Universe. However, other possible values will not vanish. By measuring, we will not exclude other possible 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. So if we had two states $A$ and $B$ with probability for example $1/2$ and $1/2$, after the measuring process we have two states $A$ and $B$, for example, one, $A$, with probability $1-10^{-3000}$ and another, $B$, with probability $10^{-3000}$. After the experiment we can't really observe the state $B$ anymore and for quite a long time, because it has so small probability, yet it does not mean it did disappear or vanish. For us the probability of $1-10^{-3000}$ is the same as 1 because whenever we combine our quantum world, us, with the system that has a state with probability of $1-10^{-3000}$, this state is the only one discernible, because 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 that system. From this experience, we have no reason to believe that other states did not really vanish, though they did not. All states always react with our own $\psi$ function, then with our eyes, brain, ... a chain of chemical reactions confirms that the state with the probability $1-10^{-3000}$ is the most probable and useful state of the system. It is only now that we deduce that this is the only existing state, because that one state is the only state that can induce a sequence of needed specific global actions in our short lifetime, at least far more effectively than the event with a probability of $10^{-3000}$.

The question is why did we have probabilities $1/2$ and $1/2$, and now we have $1-10^{-3000}$ and $10^{-3000}$? The answer lies in the measuring process itself. We introduced the apparatus with its own $\psi$ function, the function that is far more robust, strict, precise and defined than the one of the system we are measuring. We obviously forced and combined the system in observation to merge with the apparatus in order to display certain value or values. After the measuring, we do not have the system in observation any longer. Instead, we have only a combination of measuring apparatus and the system in observation. Yet the apparatus is constructed in such a way that it cannot observably stay in several states at the same time, like the system. It is constructed exactly to boost one or several specific values. By measuring we actually do not ask how the system is behaving, we are asking far more how the apparatus behaves when it is exposed to the system that we observe, and then we only deduce the system's behavior from it. Not only that we introduce apparatus, we introduce ourselves as well, with our mass, system, thoughts, experience, past, expectations, actions...

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

Now, let us imagine a standard experiment (a simplified version of 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 photon is sent but disappears only a moment before the photon reaches another half transparent mirror at the exit, we would not even notice that any barrier ever existed, yet if you take that a periodic barrier was a device, it would on its own detect a photon half times through (though we would not be able to participate in that specific measurement itself), because it was there, has combined itself with the photon, and was removed only before the photon reached the exit. Obviously although a barrier on its own should by our understanding collapse $\psi$ 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 that a barrier detects a photon is...
never in total either 1 or 0, it can only be very close to that. \( \psi \) function never collapses.

**Figure 1.** A version of standard quantum eraser experiment with two beam splitters (or half-silvered mirrors) with a periodic barrier on one of the photon’s paths. If a barrier is removed just before a photon reaches another splitter, but not before the moment at which a photon could first reach the barrier, we would not notice that a barrier was ever active. Nevertheless, the barrier, taken locally, would detect the photon half times through, so it should collapse its \( \psi \) function and we should notice that collapse if it were irreversible. (1 and 2 are beam splitters; 3 and 4 are normal mirrors.)

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

Not only apparatus, we include ourselves in the system when we observe matter. And we definitely do not know how to revert our own \( \psi \) function. Assume we revert it somehow, unfortunately this would require returning us to ignorance about the system that we measured, because our knowledge is based only on our experience, memories and observation about the system.

**Quantum-state noise**

This observation about the wavefunction that never collapses says that no information about the system is ever lost. We can retrieve from the system all previously high probable states, either if we revert \( \psi \) or if we find the way to increase the probability of states whose probability has become minute. It is as if we decreased the volume of music, but nothing is lost in the process, because if we find the way to make it loud we will hear it again in its entirety.

Mathematically speaking, if we describe a wavefunction \( \psi \) through a combination of orthogonal states \( S=\{\phi_0, \phi_1, \phi_2, \phi_3, \ldots \} \),

\[
|\psi\rangle = \sum_i c_i |\phi_i\rangle \quad \langle \phi_i | \phi_j \rangle = \delta_{ij} \tag{1}
\]

we say that throughout the history of the system:

1. either \( \phi \in S \) or \( \phi \notin S \) - the system knows all its states, no states can be added or removed

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

As usual, we can agree that probability \( p_i \) of state \( c_i \) 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 only by temporarily reducing the probability of those states we would like to exclude from our observation.

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

A measurement process equals reducing \( p_w \) and \( c_i \)’s at first in apparatus so low that only a few states of interest remain detectable within given limits (period of time and space), then combining apparatus with the tested system so that all the states, except one (or a few), have \( |c_i|^2 \leq p_w \) (i.e. have a very low probability of being detected), and only that one reaching a probability so close to 1 that subsequently we cannot observe any other possible events within given limits. Not only that. By subsequent actions, after the measuring process occurred, we reduce even more the probability of those events that were not observed during the measurement. This last is the real reason that we commonly believe that all other outcomes, save the one our apparatus or experience has shown, are not possible any longer - it is actually us who are actively reducing their probability.
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 that reason, we approximate almost everything in quantum theory; we have no other choice. The problem is in the reduction of states of a system, because 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 small probability have no influence because for us they are not interesting. 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 crucial, final role:

1. Chaos theory: any small event in a chaotic system can ignite a disproportionately large effect [Falconer; Michael]
2. Statistical theory: noise within a distribution, which can be mathematically almost ignored or disregarded, has a crucial dynamic role in shaping the final distribution measure of the system [Freedman]

If nothing else, dynamic of the system cannot be fully understood if some of its apparently unimportant states are suddenly excluded from it. Not only dynamics, but also geometry of space. 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 constantly falls on 6, so if we observe the outcome it is so constantly 1 (assuming 6 and 1 are on the opposite sides) that we have no reason to believe it is not always 1. But, if we ignore other 5 sides we might never understand the cubic shape of the die, and we know that geometry of space can have important consequences.

At the moment, we disregard the sum of states in every system whose combined probability lies beyond perceptible or measurable reality with our current technology - the quantum-state noise. Disregarding is not the problem, but what we believe, however, is that this noise can mute. It cannot. 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 ask ourselves what about the 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 has then the same form of gravity as we do.

Let us analyze other possibility, and that is that gravity (gravity is here taken as a general illustration for 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 probably cannot discuss here, since we do not know what forms gravity could have, but we can take a simple imaginative example of gravity being reversed, instead of attraction force to be a repulsive one, assuming that both were possible.)

However, from our discussion it seems that though we can observe one form of gravity, other forms are still, however unlikely and however unobservable, still possible. Now the question is, why can we observe so dominantly only this attraction-based version of gravity. The reason is actually very simple. Planets, stars, galaxies, cluster 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 do interact with that system the same way they interact with each other - we are pulled down all the time. This does not mean that other forms of gravity cannot coexist somewhere on its own with high probability, which means that certain part of the Universe might repulse (but this our attractive version would have low probability there) and we might even be able to detect some consequences of this repulsion, or whatever other form the gravity has there. 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 for us, with a specific form of gravity that definitely cannot surround us on large scale. We could not become a quantum part of that form of gravity without destruction. Those experiments related to other forms of gravity will be either very small, require 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.

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

Why don't we have to necessarily notice other versions of gravity (not to forget that gravity here is just an example)? Because it is possible that two systems of the same version of gravity interact, even if between them is a system of another type of gravity.

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

If we have two systems, X and Z, with the attractive force separated by system Y that has a repulsive gravitational 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 repulsive force, system Y might not have any influence on X or Z, only on the systems similar to Y that have repulsive force active in them. 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 attractive force of X and Z etc.

Not only that it's possible two systems like X and Z to interact, it is possible that the gravity has become an attractive force in X and in Z independently, simply because it is one of the versions of gravity that we can have from the start, and if we have for example 10 different long-lasting versions of gravities, any system on its own with as small as possible influence from other systems in the Universe will develop one of these long-lasting gravity versions at the end and start interacting with other similar and for it tractable systems, although it had nothing in common with them at start.

**Physical laws**

What we are saying here is that this same Universe can display those peculiarities on quantum level as many relatively separate big parts where each quantum inconsistency becomes consistent on its own on large scale. All these parts would still be distant and separated enough either by time or space as not to have to strongly combine or coexist with other apparent quantum inconsistencies. What is for us a combined puzzling observation on quantum level could be multiplied and developed as a separate reality on grand 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 always be ascribed to the entire Universe, however abundant it may look to us. The connection to other parts of the Universe with other laws that describe different behavior might never be possible to establish. Some laws we cherish might be, not invalid, but inapplicable to other parts of the Universe as such. (To be very precise here, when we say different laws, it means that we are able to confirm two essentially different patterns of behaviors, while we cannot find one and the same limited and relatively large environment that can display both behaviors at the same time, except on quantum level.) It means that what we could know now is what applies only to us and to our world, but in this same Universe, aliens might have very different laws based on their world and their experience. We might find the way to 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. (To make it obvious: in their world they might have some sort of magnets on their legs to attach themselves to the ground.)

Yes - because there is no law such as we know it today. Laws of 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 task is probably an infeasible endeavor.

No - because even in that other part of the Universe the laws are formed based on specific local principles - although they are different from ours, they share the same feature that their probability, or the probability of their interaction, is very high, and that fact must have a reason, some sort of explanation. So it is possible to understand them, to find a ground for existence of new combinations. It is, however, probable that even if we would understand that reality, we would not be able to use it for anything in our world on large scale. For example, it is unlikely that we could produce that much energy to annul gravity on any larger scale, because that would require to fight back all huge gravitational interaction crossed on our planet alone, but on small scale, miracles (from our common expectations) are still possible. Anyway, we would have to bring our current laws probably to a more abstract and general level in order to understand the situation in other parts of the Universe together with our current understandings. This could be the reason that we frequently need to turn to mathematics, which epitomizes much stronger and deeper enduring truths and 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 relatively long-lasting sustainable system.

It is likely that our combination of rules, expressed in form of physical laws, is actually 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 for some reason our set of laws is unique and dominant, but even then the understanding of how the set of observable laws are formed and held together is so important that the explanation of possibility of having another set of laws somewhere in this same Universe is extremely useful even if such area currently does not exist.

Unification of interpretations

We can use this perspective to unify the interpretations of quantum mechanics. We will use the thought experiment of Schrödinger's cat [Schrödinger]. The question in the cat experiment is to explain what has happened with the cat after the experiment. Is it dead or alive or both at the same time? And if it is anything, where is the information about its state hidden?

First, we repeat that a simple assumption in the new paradigm is that we never exit the quantum world. From our perspective, after the experiment, the cat is still both dead and alive, but one of two events has a very high probability. It is us who then choose to combine even further our quantum machine, us, our own wavefunction, our body, mind, ... with the outcome that has much higher probability. By subsequent actions, we tend to reduce even further the probability of the event that has much lower probability. We do that because we would waste a lot of time in trying to create a macro event out of an event that has a very small probability. In that sense, we do not make any difference between an event with the probability 1 and an event with the probability of, for example, $1 \times 10^{-3000}$. Even more, we subsequently make that $1 \times 10^{-3000}$ even smaller, because we want something to do better, more efficient. The only way to use better an event is to reduce the probability of those events that are not interesting for us. That way the event that has a high probability will be more effective.
This easily unifies the interpretations of quantum mechanics, namely: Copenhagen interpretation, many-worlds interpretation and consistent histories, ensemble interpretation, relational interpretation, objective collapse theories [Wikipedia]. Because we never leave the quantum world, its future is based on our actions. We can hold any interpretation and use it for whatever we want to do. The system will adjust to it, because it will actually fit as much as it is capable of in order to support what we believe or want to be more true. It is another question if one particular interpretation is the most appropriate for the problem we want to deal with.

To illustrate this, if we are concerned about a cat’s health, we want to strictly know what has happened to it, so it is a dead-or-alive situation for us, nothing in between, although as we said it is never only one outcome present. If it is alive, which means only that being alive has a very high probability, and it is our cat, we do not want to know about it being dead (although it is, but with a very low probability), so we are going to feed it, nurture it etc. though it will eventually meet its end. That is how we keep the probability of the cat being alive high. The dead-situation is the problem for us because the system has exited the temporary state of "being alive" and interactions that existed are beyond our current abilities of recovering - we do not know how to do that, which does not mean it is impossible. If the cat is alive, but we do not feed it, the probability of its demise is going to become all higher and higher and it will eventually die.

**Copenhagen interpretation**: we choose one, usually the most probable state or couple of states, after the experiment and actively reduce the others less interesting; all states are always present but those less probable have no macro effect that concerns us.

**Many-worlds interpretation and consistent histories**: we still choose one state, but we are aware of the influence of other states which we only displace further away to another universe where we might increase their probability and analyze a new situation; and this is correct because, obviously, we can’t have too many correlated events all with probability too close to 1 in one universe; observe that we do not have to displace all events to other universes, events can happen simultaneously in our Universe, it is sufficient that they do not interact.

**Ensemble interpretation**: we always chose one outcome, one among those more probable, and firmly believe that we never have other choices anyhow; other choices could come up only statistically through time after many repetitions; this interpretation does not want to know and deal with inner, hidden, low probable states at all.

**Relational interpretation**: the parts of the system are, for the sake of argument, observed as separated and each observer, or better say participant, can create its own choice; nevertheless, the outcome will still belong to the one who subsequently has stronger influence to the future of the system; this interpretation is aware of several states choices and does analyze all or most in parallel.

**Objective collapse theories**: there is a probability so close to 1 for an event above which its change toward 0 is very unlikely taking into account the connection between system parts; assume again that this probability is $1 - 10^{-3000}$ and the cat is at one moment dead with this probability; now something has to change it, but there is nothing in the system that can do that, and this probability $1 - 10^{-3000}$ has no reason to start reducing its value, so the observer is eventually going to find as dominant a dead-cat situation; in case the cat is alive and this much isolated as in the experiment, after some time it is going to die whatever happens, so we could say that the probability of a cat being alive is always decreasing, which is the reason we cannot reverse the explanation; collapse theories still make only one choice, but analyze what makes the probability almost fixed to very high or very low values independently and prior to any our actions.

None of the above interpretations is incorrect on its own, and all could be useful for a particular problem we would like to solve, because we usually need only some aspects of quantum world for our desirable reality view. It could be, however, that different interpretation than the one we believe in is more useful for different problems.

**Conclusions**

1. The current understanding that matter always only bears and suffers physical laws is only partially true. Matter can as well shape,
carry and define physical laws by its interaction. If a physical law has a very high probability, very close to 1, it is for us very 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 to existence; it is always true. Some physical laws came to existence and are shaped by interactions within the Universe. A principle exists in as vacuous as possible space and even beyond the Universe creation.

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 \textit{wavefunction} never collapses so that any of its states is suddenly and completely lost. Some states may have a probability very close to 0 or very close to 1, but never change the probability either to 1 or 0.

6. No information can be completely hidden, even on 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 this very low probability.

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

8. From all said above, quantum level of events does not only statistically and firmly shape larger systems. Quantum level is an active level of existence, so it is to expect that both physical and biological active processes that shape their surroundings in yet to be discovered ways exist even on quantum level.

\textbf{References}
Bohm D. Quantum theory, Dover Publications, 1989.
Cunha M, Monken C, Pádua S, Walborn S. Double-slit quantum eraser, Phys Rev A 2002; 65: 033818.
Falconer K. Fractal Geometry: Mathematical Foundations and Applications. Wiley, 2003.
Freedman D. Statistical Models: Theory and Practice Cambridge University Press, 2009.
Greene B. The Fabric of the Cosmos. Alfred A. Knopf, 2004.
Michael Berry, Quantum Chaology \url{http://www.physics.bristol.ac.uk/people/berry_mv/the_papers/Berry358.pdf}
Accessed date: July 30 2010.
Schrödinger E. Die gegenwärtige Situation in der Quantenmechanik.
Die Naturwissenschaften 23, 1935
Wikipedia, Schrödinger's cat \url{http://en.wikipedia.org/wiki/Schrödinger's_cat}
Accessed date: July 30 2010.