The quantum mechanical notion of unobservable causal loop and the anthropic principle

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Abstract

It can be argued that the ordinary description of the reversible quantum process between two one-to-one correlated measurement outcomes is incomplete because, by not specifying the direction of causality, it allows causal structures that violate the time symmetry that is required of a reversible process. This also means that it can be completed simply by time-symmetrizing it, namely by requiring that the initial and final measurements evenly contribute to the selection of their correlated pair of outcomes. This leaves the description unaltered but shows that it is the quantum superposition of unobservable time-symmetrized instances whose causal structure is completely defined. Each instance consists of a causal loop: the final measurement that changes backwards in time the input state of the unitary transformation that leads to the state immediately before it. In former works, we have shown that such loops exactly explain the quantum computational speedup and quantum nonlocality. In this work we show that they lead to a completion of the anthropic principle that allows a universe evolution with quantum speedup.

1 Summary

The anthropic principle states that our scientific observations and theories of the universe must be compatible with the development of sentient life and in particular with our existence as conscious observers [1, 2]. This principle explains physical facts that would otherwise remain unexplained. In particular, it explains why the universe must have the fundamental physical constants that it does. As it is known, on one hand, these constants are extremely unstable, in the sense that the slightest variation of their values would lead to a trivial or chaotic universe certainly unable to produce life. On the other hand, an explanation for why the fundamental constants have the value they do otherwise does not exist.

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In this paper, we propose a completion of the anthropic principle in which the presently observed state of the universe, comprising sentient life, not only justifies the values of the fundamental constants, but also contributes to setting them in a way that makes sentient life possible. This is based on the recent finding that the reversible quantum evolutions between two one-to-one correlated measurement outcomes host unobservable causal loops [3].

Such causal loops are highlighted by time-symmetrizing the ordinary quantum description of the processes in question. This leaves that description unaltered but shows that it is a quantum superposition of causal loops, each a quantum measurement that changes backwards in time the input state of the unitary transformation that leads to the state immediately before it. These loops are unobservable since an observer external to the quantum process cannot say whether the outcome of an initial measurement, or part of it, has been selected by that very measurement or is the backwards in time propagation of a selection performed by the final measurement. Although unobservable, such causal loops have an explanatory power of what happens inside the quantum process superior to that of their quantum superposition, namely the ordinary quantum description in which they vanish.

In former works [3, 4], we have shown that quantum causal loops exactly explain the quantum computational speedup and quantum nonlocality. As we will see, the notion that the presently observed state of the universe contributes to selecting the universe initial state has a variety of consequences, in the first place the possibility that the evolution of the universe that we observe today underwent with a quantum speedup, namely a speed unreachable in the classical case.

Below, we first review the notion of quantum causal loop and its application to the quantum computational speedup and quantum nonlocality. We then show how this notion could be merged with the anthropic principle.

2 The notion of quantum causal loop

We consider the reversible quantum processes between two one-to-one correlated measurement outcomes. Note that these processes are reversible in spite of including the final quantum measurement. In fact the latter, giving an outcome one-to-one correlated with that of the initial measurement, does not lose any information.

The fact that these processes host quantum causal loops can be derived as follows:

i) Right because of their time-reversibility, the ordinary quantum description of the processes in question describes the correlation between the two measurement outcomes but not the time-directions of the causations that ensure it. The initial outcome, or part of it, can be the cause of the final outcome,

1We call the usual quantum description ordinary to distinguish it from the completed quantum description that we are going to propose.
or the corresponding part of it, or vice versa. However, this allows causal structures between the two outcomes that violate the time symmetry that should be required of the description of a reversible process. An obvious violation of this time-symmetry comes from the usual interpretation of the ordinary description of the quantum process itself, for which the outcome of the initial measurement is the cause of that of the final measurement.

ii) Of course such an incompleteness is simply avoided by time-symmetrizing the quantum description. We should evenly share between the initial and the final measurements the selection of the information that specifies the sorted out pair of correlated measurement outcomes among all the possible pairs. Since there is a plurality of ways of halving this information, we should take their quantum superposition.

iii) Things should go as follows. In each element of the superposition, the initial measurement selects one of the possible halves of the information that specifies the pair of outcomes. The corresponding outcome unitarily propagates forward in time until becoming the state immediately before the final measurement. The final measurement selects the other half of the information. The corresponding outcome unitarily propagates backwards in time, by the inverse of the previous unitary transformation, until it becomes the definitive outcome of the initial measurement. This last propagation, which inherits both selections, is an instance of the time-symmetrized process.

iv) The ordinary quantum description remains unaltered under the time-symmetrization in question – this was naturally due since the description of a time-reversible process must be time-symmetric to start with. However, the same description turns out to be the quantum superposition of unobservable time symmetrization instances whose causal structure is completely defined. Each instance hosts a causal loop, the final measurement changing the input state of the unitary transformation that leads to the state immediately before it.

For the fact they take the direction of the causations into account, the time-symmetrization instances in question have an explanatory power of what happens inside the quantum process superior to that of their superposition. In particular, they provide an exact explanation of two otherwise unexplained phenomena: the quantum computational speedup and quantum nonlocality [3, 4].

As well known, that quantum nonlocality is mathematically but not physically explained by the ordinary quantum description was first noted by Einstein, Podolsky and Rosen [5] in 1935. Of course, the ordinary quantum description mathematically describes instantaneous action at a distance, but does not explain it physically.

The notion of quantum computational speedup is a more recent development, although with a long history. In 1969, Finkelstein [6] showed for the first time that computation is feasible in the quantum framework. In 1982, Feynman [7] first noted that quantum computation can have a higher efficiency.

\[2\] Up to an irrelevant inversion of all the time-directions of the causations together. This of course leaves the sharing of the selection of the information between the initial and final measurements even.
than classical computation. In 1985, Deutsch [8], also relying on the notion of classical reversible computation in the meantime highlighted by Bennett [9] and Fredkin&Toffoli [10], devised the seminal quantum algorithm that yields a speedup with respect to its best possible classical counterpart. After that, many tens of quantum speedups have been discovered, some of potentially enormous practical interest. We recently argued that the quantum speedup shares with quantum nonlocality the identical problem [3]. The ordinary quantum description of course mathematically foresees the quantum speedup quantum algorithm by quantum algorithm, but does not explain its constant physical reason, which by the way turns out to be the same of quantum nonlocality, in fact a causal loop.

2.1 Causal loops and the quantum computational speedup

By quantum computational speedup one means the fact that, in the quantum world, one can solve problems with fewer computation steps than in the classical one. Consider for example the following problem. Bob hides a ball in a chest of 4 drawers, which we number in binary notation 00, 01, 10, 11. Say that he hid the ball in drawer 01. Alice must identify the number of the drawer with the ball by opening drawers. In the classical world, if she is lucky, Alice finds the ball in the first drawer opened. But, in the worst case, she has to open three drawers. If the ball is in the third drawer opened, she has solved the problem. If it is not, it must be in the drawer that she has not yet opened and she has solved the problem as well. In the quantum world, instead, the ball is always located by opening only one drawer, in a quantum superposition of all the drawer numbers. There is a quantum computational speedup – in fact the one of the famous quantum algorithm of Grover [11].

Let us describe the key steps of Grover algorithm. We follow the canonical way of describing a quantum process: initial measurement, unitary evolution, and final measurement. See the following table, from now on we disregard normalization:

\[
\begin{array}{c|c}
\text{time } t_1, \text{ meas. of } \hat{B} & \text{time } t_2, \text{ meas. of } \hat{A} \\
(\langle 00 \rangle_B + \langle 01 \rangle_B + \langle 10 \rangle_B + \langle 11 \rangle_B) |00\rangle_A & \\
\downarrow & \\
|01\rangle_B \langle 00 \rangle_A & \Rightarrow \hat{U}_{1,2} \Rightarrow |01\rangle_B \langle 01 \rangle_A
\end{array}
\]

(1)

We need two quantum registers. Register \( B \), under the control of Bob, contains the number of the drawer with the ball (the problem-setting). Initially, it should be in a superposition of all the possible numbers of the drawer with the ball – top-left corner of the diagram. Register \( A \), under the control of Alice, is initially in any sharp state which stands for a blank blackboard (finally it will contain the solution of the problem). The initial measurement of the content of register \( B \) (the observable \( \hat{B} \)), performed by Bob at time \( t_1 \), randomly selects
a specific number of the drawer with the ball – say 01 – vertical arrow on the left of the diagram. The subsequent unitary transformation $U_{1,2}$ is the unitary part of Alice’s problem-solving action – bottom line of the diagram. It changes the blank blackboard in register $A$ into the solution of the problem, the number of the drawer with the ball selected by Bob – bottom-right corner of the diagram. The measurement of the content of register $A$ (the observable $\hat A$), performed by Alice at time $t_2$, selects with probability 1 the solution of the problem, the quantum state remains unaltered (note that $\hat B$ and $\hat A$ are commuting observables).

Also note that this description of the quantum algorithm properly works for Bob and any external observer, but cannot work for Alice. Immediately after the initial measurement, it would tell her that the number of the drawer with the ball, the solution of the problem, is 01. Of course the solution should be concealed from the problem solver Alice. To physically represent this concealment, in the first place we must resort to relational quantum mechanics, where the quantum state is not absolute but relative to the observer [12, 13]. This allows us to have a description of the quantum algorithm with respect to Bob and any external observer – that of table (1) – and a different one with respect to Alice. The latter description is simply obtained by postponing, by $U_{1,2}$, the projection of the quantum state due to the initial Bob’s measurement to the end of Alice’s problem-solving action. The result is given in the following table:

| Time $t_1$, meas. of $\hat B$ | $t_1 \rightarrow t_2$ | Time $t_2$, meas. of $\hat A$ |
|-------------------------------|----------------------|-------------------------------|
| $|00\rangle_B + |01\rangle_B + |10\rangle_B + |11\rangle_B \rangle A$ | $U_{1,2} \Rightarrow |00\rangle_B |00\rangle_A + |01\rangle_B |01\rangle_A + |10\rangle_B |10\rangle_A + |11\rangle_B |11\rangle_A \Rightarrow |01\rangle_B |01\rangle_A \rangle$ | (2) |

To Alice, the initial superposition of all the possible numbers of the drawer with the ball remains unaltered through Bob’s initial measurement – top-left corner of the diagram. This superposition represents her complete ignorance of the number of the drawer with the ball. It evolves, by the unitary part of her problem-solving action $U_{1,2}$, into a superposition of tensor products, each a number of the drawer with the ball in register $B$ multiplied by the corresponding solution, that same number but in register $A$ – top-line of the diagram. Eventually, by measuring $\hat A$, Alice projects the latter superposition on the tensor product corresponding to the number of the drawer with the ball initially selected by Bob – vertical arrow on the right of the diagram. Note that this projection is also that due to Bob’s initial measurement, postponed by $U_{1,2}$.

We go now to the time-symmetrization of the quantum algorithm to Alice. Let us consider the instance where the number of the drawer with the ball is 01, the initial measurement of $\hat B$ reduces to that of $\hat B_l$ and selects the left digit of the number in register $B$, namely the 0 of 01, and the final measurement of $\hat A$ reduces to that of $\hat A_r$, and selects the right digit of the number in register.
A, namely the 1 of 01. This is one of the possible ways the initial and final measurements evenly contribute to the selection of the number of the drawer with the ball 01. See the following table:

| Time $t_1$, meas. of $\hat{B}_l$ | $t_1 \Rightarrow t_2$ | Time $t_2$, meas. of $\hat{A}_r$ |
|-----------------------------------|----------------------|-----------------------------------|
| $|00\rangle_B + |01\rangle_B + |10\rangle_B + |11\rangle_B\rangle_00\rangle_A$ | $\Rightarrow \hat{U}_{1,2} \Rightarrow |00\rangle_B|00\rangle_A + |01\rangle_B|01\rangle_A + |10\rangle_B|10\rangle_A + |11\rangle_B|11\rangle_A$ | $\downarrow$ |
| $|01\rangle_B + |11\rangle_B\rangle_00\rangle_A$ | $\Leftarrow \hat{U}_{1,2}^\dagger \Leftarrow |01\rangle_B|01\rangle_A + |11\rangle_B|11\rangle_A$ |

Alice does not see the projection of the quantum state associated to the initial measurement of $\hat{B}_l$. Any information about the number of the drawer with the ball should be concealed from her – top-left corner of the diagram. That projection must be postponed, by $\hat{U}_{1,2}$, to the end of Alice's problem-solving action – outside table (3) which is limited to this action. Thus the top line of the diagram is the same of the table (2). The final measurement of $\hat{A}_r$ projects the final superposition on the superposition of the two tensor products ending with the digit 1 of 01 – vertical arrow on the right of the diagram. Eventually this measurement outcome propagates backwards in time by $\hat{U}_{1,2}^\dagger$ until becoming the definitive outcome of the initial measurement – bottom line of the diagram.

This bottom line of the diagram, which inherits both selections, is an instance of the time-symmetrization of the quantum algorithm to Alice. Of course it can be read in equivalent terms in the usual left to right way as:

$$
|01\rangle_B + |11\rangle_B\rangle_00\rangle_A \Rightarrow \hat{U}_{1,2} \Rightarrow |01\rangle_B|01\rangle_A + |11\rangle_B|11\rangle_A
$$

In any of these instances, the computational complexity of the problem to be solved by Alice reduces to locating the ball hidden in one of 2 drawers (instead of the original 4, where $2 = \sqrt{4}$), here it becomes locating the ball hidden in the pair of drawers 01 and 11 – compare the input and output states of $\hat{U}_{1,2}$. Correspondingly, Alice knows in advance that the ball is in one of two drawers instead of the previous four – see the superposition of basis vectors of register $B$ in the left of table (4). Of course the superposition of all the pairs of drawers is the superposition of all the drawers of the quantum algorithm to Alice of table (2). In other words, the superposition of all the time symmetrization instances is the ordinary quantum description of the quantum algorithm to Alice again.

The reduced complexity problem, as any other problem, can always be solved quantumly with the number of computation steps (here drawer openings) required by a reversible classical algorithm – i.e. logically required. The question then becomes whether it could be solved with even fewer drawer openings, namely itself with a quantum speedup. Now, under the reasonable assumption that the quantum speedup is essentially related to the reduction, under time-symmetrization, of the computational complexity of the problem to be solved, the answer must be negative. In fact, the quantum algorithm that solves the reduced problem has been time-symmetrized already. Further time-symmetrizing
it would leave it unaltered without further reducing the computational complexity of the problem.

Summing up, Alice knows in advance half of the information about the solution she will produce in the future and can use this knowledge to produce the solution with fewer drawer openings – with the number logically required to go from the input to the output of \( \hat{U}_{1,2} \) in table (4). This is of course a causal loop.

Let us emphasize the peculiarity of this situation as follows. If Alice knew in advance not 50% but all the information about the number of the drawer with the ball, we would be dealing with a typical science fiction plot. The one about the scientist who invents the time machine and uses it to send to herself, back in time and before her invention, the design of the machine. Of course also a loop limited to the advanced knowledge of 50% of the information about the solution that the problem solver will produce in the future may seem paradoxical, but in this case there are both a justification and a remedy.

The justification is that the loop is originated by a legitimate time-symmetrization operation. The remedy is that it vanishes in the ordinary quantum description – in the superposition of all the time symmetrization instances. We have seen that the ordinary quantum description, the superposition of all the time symmetrization instances (each a causal loop), remains unaltered under the time-symmetrization process. Therefore the causal loop does not change the past as described by the ordinary quantum description, it just explains what went on inside that description.

By the way, instead of causal loops, one can speak in equivalent terms of mutual causality. In each time-symmetrization instance, everything goes as if the final measurement of the solution by the problem solver contributed to the initial selection of the problem-setting by the problem setter. Because of this, the problem solver knows in advance one half of the information about the problem-setting, the half that she herself has set.

In the general case – in the case of any oracle problem\(^3\) – everything goes as if the quantum problem solver knew in advance half of the information that specifies the problem setting and thus the corresponding solution of the problem and could use this knowledge to solve the problem with the number of computation steps (oracle queries) required to solve it classically. We should remember that the problem-setting must be hidden from the problem solver, to her it should be inside a black box. In particular, this finding constitutes a synthetic solution of the central problem of quantum computer science, the so-called quantum query complexity problem. The problem is: given an oracle problem, find the number of oracle queries needed to solve it in an optimal quantum way. By synthetic solution we mean a solution that is derived axiomatically from fundamental physical principles, in this case simply from the requirement that the quantum description of a reversible physical process is time-symmetric.

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\(^3\)Grover’s problem is an oracle problem: given a set of functions, in this case the set of the Kronecker delta \( \delta (b, a) \) where \( b \) is the number of the drawer with the ball and \( a \) that of the drawer opened by Alice, find \( b \) by evaluating \( \delta (b, a) \) for different values of \( a \). Function evaluation is also called oracle query.
2.2 Causal loops and quantum nonlocality

Causal loops also provide a local explanation for quantum nonlocality. Here the two one-to-one correlated measurement outcomes are those of the measurements in the same basis of two maximally entangled observables whose respective subsystems are space-separate. Mathematically, the measurement of the observable of one subsystem instantaneously changes the state of the other subsystem, even though it is space-separate from the first subsystem. Of course instantaneous action at a distance is physically unexplained.

This time it is explained by two causal loops, one for each measurement. In each of them, the measurement of the observable of the respective subsystem changes backwards in time, at the time when the two subsystems were not yet space-separate, the state of both subsystems. This locally ensures the future correlation between the two measurement outcomes – see [3] for more detail.

Let us see why, in the case of nonlocality, there are two causal loops instead of the single one of the speedup. Also in the speedup case the initial measurement (which selects half of the information about the pair of outcomes) contributes to the determination of the final measurement outcome, but this in an entirely time-forward way, without any time-loop. In the nonlocality case instead, the outcome of either measurement contributes to the determination of the outcome of the other measurement by undergoing the unitary transformation that physically connects the two measurement outcomes via the time the two subsystems were not yet space separate, thus first backwards then forward in time. There are two causal loops.

3 Merging the notion of causal loop and the anthropic principle

Let us consider a toy universe whose evolution is mappable on the process of solving in the quantum way the four-drawer problem. We should assume that:

a) The numbers of the drawer with the ball, say, 01 and 10 signify life-compatible fundamental constants, 00 and 11 incompatible.

b) Before a hypothetical initial measurement, the toy universe is in a uniform quantum superposition of the four possible numbers of the drawer with the ball – of all the possible universes to use the words of Leibniz.

c) In the ordinary description of the quantum process, the initial measurement outcome unitarily propagates forward in time until becoming the outcome of a final measurement (or sequence of measurements) that selects the universe that we observe today, with its corresponding fundamental constant, i.e. number of the drawer with the ball.

We should now time-symmetrize the ordinary quantum description of the time-reversible process between the two measurement outcomes. In each time-symmetrization instance, half of the information that specifies the number of
the drawer with the ball – i.e. the type of fundamental constant – is selected by the initial measurement, the other half by the final measurement.

Let us take the instance where, say, the initial measurement selects the left digit of the number of the drawer with the ball and the final measurement selects the right digit. Suppose that the initial measurement randomly gives left digit 0. Since we are now in a universe compatible with life, the final measurement must give right digit 1. The overall measurement outcome, either the number of the drawer with the ball or the type of fundamental constant, is then 01. Of course this interpretation would be unobservable, indistinguishable from the one in which the whole number 01 is entirely selected by the initial measurement. However, like in the problem-solving case, it yields consequences. The more objective one is the possibility that the universe evolution that we know underwent with a quantum speedup with respect to any possible classical evolution, as follows:

i) Say that the observed evolution of our universe benefited from a quadratic quantum speedup, like that of Grover algorithm.

ii) A quadratic speedup could imply a time constant for the evolution of life dramatically different from that of a classical evolution. Let us assume that this time constant for the universe we live in is that of the earth, roughly 10 billions of years from the big bang. Of course, we do not know the size of the problem of producing life. However, to give an idea of what could mean a quadratic speedup, let us think that the problem is that of locating the ball in a certain number of drawers. Assuming that one opens a drawer every second, taking 10 billion of years with a quadratic speedup means that there were about $10^{35}$ drawers. To solve this problem classically (without speedup) would require 10 billions of billions of billions of years. This is to say that the difference between the two time constants may not be peanuts, and that ignoring the possibility that the evolution of life occurred with a quantum speedup may prevent us from understanding it.

iii) In particular, to assume that the evolution of life occurred with a quantum speedup is to assume that there was a preference for those mutations that would have provided, in the future, the greatest evolutionary advantage. Of course, a Darwinian evolution with such a forecasting ability would have a dramatic advantage over the classical Darwinian evolution we have always thought of.

iv) How takes place the transition from organic molecules to the most simple self reproducing form of life is still an open problem. As well known, there is a huge jump in complexity from the simplest self-replicating system and its molecular soup, and how this jump came about is the problem. Perhaps this problem could be faced with the help of a new concept. The concept that, at the quantum level, non-living existence orients its development towards the living one by benefiting from half of the information encoded in the living stage.

v) Points (iii) and (iv) might also suggest concrete research directions in quantum information science. As one looks for new quantum algorithms for problem solving, one could look for toy situations where the increase of the
fitness of a system to its external environment, or the development of a self replication capability, occurs with a quantum speedup. If feasible, such toy models could constitute a conceptual reference for the research of molecular quantum evolutions.

Naturally, a causal loop can have far-reaching implications, below we give some possible philosophical implications:

iv) A possibility is merging the quantum causal loop notion with John Wheeler’s notion of observer-created reality. According to the latter, the quantum observer, via the mechanism of delayed choice experiment, would create the fundamental physical laws at the beginning of the universe [14,15]. This merging would introduce an important difference. Wheeler assumes the propagation backwards in time of 100% of the information that specifies the final measurement outcome. We have seen that this would be like the inventor of the time machine that sends back in time to herself the machine design. It would violate the time-symmetry required of the description of a reversible quantum process and would thus be unphysical. We should replace Wheeler’s observer-created reality by a reality that, for one half of the information that specifies it, is selected at random among all the possible realities and, for the other half, is created by the observer. This would satisfy the time-symmetry in question and might be physical.

v) A reality partly created by the observer could provide a scientific foothold to Fritjof Capra’s idea of a congenerity between the fundamental states of consciousness described by eastern theosophies and our perception of the fundamental laws of modern physics [16]. It could also explain the intelligibility of the universe, the fact that we can perceive the fundamental physical laws.

vi) Also the central idea of idealist philosophy, that reality is created by our mind, could find a scientific foothold hitherto unsuspected.

vii) The same scientific foothold could apply to the philosophical notion of teleological evolution.

viii) The quantum causal loop, like any time loop, can be seen as something that is run only once or any number of times. If we think that the cosmological quantum causal loop would include our innate will to exist, we get something similar to the concept of eternal return theorized by the philosopher Friedrich Nietzsche.

ix) The idea of a reality created with the contribution of the observer, perhaps allowed by the notion of quantum causal loop, could foster less enmity and more fusion between scientific and philosophical thinking.

x) The above vision of a cosmological quantum causal loop might have to do with Everett [17] many worlds interpretation of quantum mechanics. If, before the final observation/measurement, the universe must be in a quantum superposition of universes with fundamental constants both compatible and incompatible with life (in the above toy universe only the digit 0 of 01 is selected by the initial measurement), before the final measurement we must have the parallel universes of the many worlds interpretation. A possible difference is that the final act of observation must reduce the number of parallel universes to those compatible with life.
4 Conclusion

Summarizing, we have focused on the reversible quantum processes between two one-to-one correlated measurement outcomes. The initial outcome can differently be the number of the drawer with the ball of Grover algorithm or the initial state of the universe, selected from all the possible drawer numbers or all the possible universes respectively. The final outcome is the solution of the problem or the presently observed state of the universe, respectively. Our argument develops as follows:

a) The ordinary quantum description of the unitary evolution between the two measurement outcomes is incomplete: it allows causal structures that ensure the correlation between the two outcomes but violate the time-symmetry required of the description of a time-reversible process.

(b) Then it is completed simply by time-symmetrizing it. This leaves the description unaltered, as it had to be, but shows that it is the quantum superposition of unobservable time-symmetrization instances whose causal structure is completely defined. Each instance is a causal loop: the final measurement that changes the input state of the unitary evolution that leads to it.

c) These causal loops have greater explanatory power of what happens inside the process than their superposition, where they vanish. They exactly explain the quantum computational speedup and quantum nonlocality.

The standard formulation of the anthropic principle takes into account the correlation between the fundamental physical constants and sentient life but leaves the causal structure that ensures this correlation free, also free of violating the time-symmetry of the description of the process in between – like the assumption that causality goes only forward in time. This formulation is then incomplete exactly as the ordinary quantum description. And it can be completed as well by taking into account the time-symmetrization instances of the evolution of the universe between the initial and final measurement outcomes. These are the unobservable causal loops in which the currently observed state of the universe and sentient life contribute to determining its initial state and the fundamental constants. As exemplified by points (i) through (x), such causal loops would have an explanatory power of what happens inside the evolution greater than that of their superposition, namely the standard anthropic principle.

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