The Time’s Arrow within the Uncertainty Quantum

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Abstract

A generalized framework is developed which uses a set description instead of wavefunction to emphasize the role of the observer. Such a framework is found to be very effective in the study of the measurement problem and time’s arrow. Measurement in classical and quantum theory is given a unified treatment. With the introduction of the concept of uncertainty quantum which is the basic unit of measurement, we show that the time’s arrow within the uncertainty quantum is just opposite to the time’s arrow in the observable reality. A special constant is discussed which explains our sensation of time and provides a permanent substrate for all change. It is shown that the whole spacetime connects together in a delicate structure.
1 Introduction

In searching for a linkage between the two realms of classical and quantum physics, many researchers have restricted themselves with highly idealized models amenable to exact solutions. While being helpful to our knowledge of the border-crossing between the two realms[1], this may also get too much of our attention to the well-defined process[2-4], so that less notice is taken of the simple yet profound similarities of some physical process between the two realms. That may be partly the reason that some physicists suggest satirically that papers in theoretical physics nowadays refer only to other papers (and quite often, only to other papers in theoretical physics). To our knowledge, very few people have study the implication of the quantum aspect of measuring process in classical physics. By that I mean, while so much unfruitful effort has been made to understand the meaning of quantum measurement, can we bypass the difficulty by looking for masked quantum behavior in classical area? A way for doing this is to examine the similarity in measuring process between classical and quantum physics. We know an observer is needed in order for the wavefunction to collapse (from ?) to reality, while in classical physics the observer seems unnecessary. In fact, in both cases a measuring unit is needed for the measuring result to be meaningful, which has the quantum feature, i.e. subjectively uncertainty. Measuring unit and the result together compose a measurement. In both classical and quantum physics, the Second Law is observed for all measurement results. Does it have any difference for the measuring unit? Directed under such notion,
we find some interesting and profound aspects for time’s arrow, as well as a
generalized framework to reconcile classical and quantum physics.

Time’s arrow has been one of the most puzzling problem in modern physics.
Though inner-time scale[5] in various phenomenological problems adds comple-
mentarily to the second law, no satisfactory explanation out of those precise and
reversible fundamental physics theory has been found. What has been made
clear is, it seems to me, the problem is related to other difficulties just as great.
For examples, Poincare Recurrence[6] hints that time’s arrow may be related to
the meaning of infinite in mathematics. And Schroedinger Cat and other para-
doxes[7] in quantum theory show, according to some physicists, that measuring
process is time-unsymmetrical so that time seems related in a complex way to
a more mind-boggling concept, spirit. It’s a wonderful idea to consider[8] that
moments separated in time, just like elements separated in space, are genera-
ally "non-causally and non-locally related projection" of a higher-dimensional
reality. But I never think that a description with higher dimension will lead
to a better understanding of the problem, simply because it’s only mathemat-
ical skill, not true in reality. Physics should lead to, I believe, an overall and
self-contained understanding of the world, not just empirical skills in prediction.

Therefore much more revolutionary changes in ideology is needed to under-
stand the meaning of time. This may account for the present difficulty in the
research of time and related problems. In developing the widely expected theory
of quantum gravity, some physicists[7] believe that time is deeply involved in
the theory, and even suggest that the success of the theory depends on some
great changes to our idea of space and time. I quite agree on this point. But I
would like to argue in this paper that isn’t the problem caused by our mixing
up the two different concepts, time in physics and time in reality? As has been
well established since Boltzmann, time’s arrow in physics is generally referred to
an irreversible process, which is unsymmetrical in time. We have been so sure
of this because reversible process gives no direction, yet time in reality does
exist. Here I’d like to point out that it may be a big mistake to relate time with
irreversibility, which has deep repercussion. Time embodies itself not only in
irreversible changes, but in all changes including reversible changes. With this
notion, we can naturally develop an understanding of time by examining the
basic feature of measurement and the similarity in measuring process between
classical and quantum physics. We shall see that quantum theory, with some
extension to what has been expressed with ”multi-world” theory[9], can give
self-contained explanation for time without resort to the paradoxical anthropic
principle.

Therefore we are going to show that time and the measuring difficulty in
quantum physics can be considered as different projections of a single problem.
Comparing with quantum physics, we are going to point out that all measurable
quantities in classical physics, especially space, time and mass, are in quanta
(uncertainty quanta, as we call it), which are the smallest uncertainty units
that compose the observable quantities. By designing a generalized framework
of observables, we can describe a system with a set of possible states. This is different from the description with a wave function which only depicts a virtual reality, to be ready to collapse with measurement. We shall show in later works that in such a generalized framework, causality restriction established by relativity and nonlocal correlation in quantum theory can be reconciled. When this new method of description is applied to the whole universe, we find a simple yet profound symmetry for all possible states of the universe. More important, this symmetry is employed to show that time’s arrow within the uncertainty quanta is just opposite to the time’s arrow in our observable reality. It is also possible to see the nature of irreversibility within such a framework. All these conclusions support the philosophical viewpoint of quantum theory that any relation is meaningless unless we clearly indicate the observer or subject.

2 State Set and Time’s Arrow

In quantum physics, the state of a system is described with a wave function, whose evolution is dominated by a deterministic equation. The most important thing here is, the wave function is not the reality. Reality is the result of measurement of some observables, whose probabilities can be calculated from the wave function, the virtual reality. Thus in this precise theory reality has no real meaning without measurement. This is the basic difference between classical and quantum physics, and also the first point where we are to make
some discussion. In our research, we try to deal directly with reality, rather than the virtual reality described with wave function. That is, we concentrate on what variables describe the system, rather than what the wavefunction will evolve. There is no point to talk about the state of a system without measurement. In doing so, the role of the observer is emphasized. So we define a set of states of some observables, the state set, to describe the present state of the system in research. The state of the system in the next moment may be described with another state set. Thus the evolution of a system is described with a series of state sets in different moments, which, with the name of uncertainty quanta of time, naturally depict a picture of quantized time. Here we shall not talk about the dynamical law dominating the evolution of the state set in time, because we are studying time itself. Rather, from the perspective of a special symmetry between different state sets, we shall see the nature of time. We hope that such a set description will still be fruitful in the research of other problems.

The second important point in our research is that we always concentrate on the role of the observer. We shall never discuss an absolute object without any observer. Any system in research is regarded as the environment of a certain observer. When the system is all of our research, it is all of our environment. Thus the state set actually describes the environment or the state of an observer. That is, we concentrate on the observer, rather than an objective system which is always the environment of an observer. We put special stress on this point because it seems to me that the measuring difficulty in quantum theory arises
mainly from the absolute objectivity of reality that has been widely admitted since Galileo’s time. As will be shown, such absolute objectivity is just as questionable in classical physics as in quantum theory.

In order to introduce some important concepts, a generalized framework of quantum theory is needed. We divide all observables into three groups: the present observables, the outer observables, and the inner observable. The present observables describe the state of the environment (e.g. the system in our research) at the present moment. The inner observables are those that are not commutable with the present observables. All possible states (or values) of inner observables compose the inner environment (referred as IE in the following). The outer observables are those that are commutable with the present observables. All possible states of outer observables compose the outer environment (referred as OE in the following). The state set comprises the measured state of the present observables and outer environment. It is evident that OE can be observed at present state while IE can not. Another important difference between IE and OE is: all states in OE are equivalent while all states in IE are totally uncertain. This is because that all states in OE are measurable but we do not measure, or do not distinguish them. Therefore these states are equivalent to us observer and do not give us the sense of time. That is, OE gives no sense of time and all states in OE are time symmetric. But we can talk nothing about IE because we have not a bit of information about it. It may have any unexpected amount, structure or property. As we shall discuss in other work,
this complete uncertainty of IE makes convergence in many cases precarious.

Now we are ready to define the most important observable, $A_0$, which is defined to be commutable with all inner and outer observables. Since we give no restrictions to the symmetry of the variables, $A_0$ can be nothing but only a constant. That is, its eigenvalue is a constant, never changing in time. As we discussed in the introduction of this paper, time is related with change in our theory. Therefore we can not talk about time before we understand the meaning of change. This requires that we have something that never changes. All dynamics fix the meaning of time to study the meaning of change. This has to be reversed if we are to study the meaning of time. The constant $A_0$ means we now have found something perpetual. This is important because it provides a perpetual substrate for all changes. Without it, change would have no meaning, so that we have no ways to discuss time. It is this constant that enables us to sense the time. Since $A_0$ is commutable with all observables and has only one possible value, it is always a present observable. When $A_0$ is the only present observable, all states of the environment are in the OE and the IE is null. In such a case OE is the Whole Environment (referred as $WE$ in the following). We express $WE$ as a set composed of all possible states of the world, in which all states are equivalent or time-symmetric because $WE$ is the OE of $A_0$.

$$WE = \{ \phi_i \mid P\phi_i = \phi_i, \text{ for all } i \} \quad (1)$$

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where $P$ is the exchange operator related with the symmetry in OE. Since $A_0$ is always a present observable, this symmetry is perpetual. This perpetual symmetry has tremendous philosophical meaning: we make all measurements on such a substrate state in which all states are equivalent and give no sense of time, and we observe all changes with comparison to a perpetual substrate state which contains all states and has no change because all states are equivalent. That is, change means deviation from the state $A_0$.

Generally an observer always has some specific observables as his present observables. Therefore what he observes is only a part of $WE$ so that his state set is a subset of $WE$.

$$A = \{ \phi_i \mid P\phi_i = \phi_i, \, \phi_i \in OE^A \} \quad (2)$$

where $OE^A$ is the OE of state $A$. Such a state set describes the state of the observer within that shortest time interval (time quantum). Since outer observables are commutable with present observables and all states in OE are equivalent, the OE actually represents the choices that the observer can make in the state represented by $A$. Thus if we can find new equations reversibly connecting states which are not reversible to us before, our OE is then enriched. It is evident that the more ordered observer should have more states in his OE, which give no sensation of time but just furnish the environment with symmetric or reversible states (thus an more ordered observer has slower watch. We’ll come to this point later). That means, reversibility is possible only between states in
OE. The states in IE represent the defect or limitation of the observer system, because they can not be measured without losing present information. They are unsymmetrical compared with the states in OE. We shall show that it is this part of WE, the complementary set of the state set, that really gives the system the sensation of time.

Since $A_0$ is always a present observable, all states in $WE$ are symmetric. To keep this perpetual symmetry, the observer must have a state set, which is exactly the complementary set of the present state set, in another moment. That is, IE and OE will change their role in order to keep $A_0$ a perpetual constant. Or, all states comes together with their respective complementary states, with one to be the present and the other to be the future (for some specific observer, of course. This sort of relativity has already been made known by Einstein).

Thus the broken symmetry of the states in $WE$ leads to the unfolding of time, in which the symmetry in $WE$ gets realized.

In the above picture, we can find the time’s arrow that is opposite to the Second Law, or to that in our present reality. In fact, time exists for an observer only because the OE is only part of $WE$, i.e., it is the result of the broken symmetry in $WE$. Therefore a perfect observer that has $WE$ as its OE would have no time. Suppose the outer environment of observer X experiences a process P that can be described consecutively with states $A_1, A_2, \ldots, A_k$. Then the time’s arrow for X would be given by the series
\[ T : A_1, A_2, \ldots, A_k \]

Because of the perpetual symmetry, all the complement of the states will come true to the system in other moments. Obviously in order to maintain the perpetual symmetry they will come true in such an order.

\[ T' : A'_1, A'_2, \ldots, A'_k \]

Since \( A_1 \) and \( A'_1 \), \( A_2 \) and \( A'_2 \), \ldots, \( A_k \) and \( A'_k \) are all complements to each other, a physical observable that increases in the process \( T \) will decrease in the process \( T' \). Thus theoretically we may expect that the Second Law is reversed in other time (before or future) with regard to our present state. Just as infinite in mathematics can not be clearly figured out, \textit{we can not see this without losing present information} (e.g., classification, function or nature of observables), because they are in IE to our present state. It should be noted here that there is no restriction that the observer in the state \( A \) must fall into the state \( A' \) immediately. He may continue to choose new environment from the symmetric states within its state set. This may be called the free will of the observer. Yet From the perpetual symmetry it is sure that the process \( T' \) will come true for the observer. Then he will lose some his present information, which has been widely admitted to be the symbol of time’s arrow. That is doomed contingency for any observer system. Therefore time’s arrow exists for all observers, which changes its embodiment in accordance with the state set.
What I try to emphasize in this paper is we don’t need the infinitely long Poincare Recurrence to see the opposite time arrow. It functions within the uncertainty quanta as we shall show in next Section. Here we briefly discuss the matter from the perspective of a perfect observer. For each system X, there will be a system X’ which is the conjugate system of X, because a perfect observer has WE as its OE. Therefore, according to the perpetual symmetry of WE, when an observer system takes a state set A from WE, there must be another observer taking the complement set A’ to maintain the symmetry. This means, the two observers are equivalent and symmetric in position or status. Both are concealed in the IE, or limitation of environment of the other observer. Most important, they will exchange their roles in their respective future to get the perpetual symmetry realized for each observer. Thus when X experiences an event described as $A \rightarrow A'$, its conjugate system $X'$ just simultaneously experiences the opposite procedure $A' \rightarrow A$. Both system have their own second law and time’s arrow. But their limitations restrict them from knowing the opposite process and fail to see the perpetual symmetry. In fact, both system compose the limitation of the other system. This is just what happens within the uncertainty quantum, which is the smallest unit of measurement for an observer. Therefore when entropy increases in our environment, it decreases within our limitation of measurement, or in the inner environment that we can not identify because of our limitation.
3 Measurement and Uncertainty Quantum

With the change from wave function description to state set description, the role of measurement has been emphasized. Any state of a system is closely related to measurement, which is in turn attributed to an observer, thus we talk about the state of the observer instead of its object system. The consideration of measurement naturally divides all states into OE and IE. The collapse of the wave function means nothing but the selection of a new state set. The definition of observer in physics is just the ability of selecting state sets. As a matter of fact, life has nothing more than the ability of distinguishing or selection. Such ability arises because an observer always has $A_0$ as his present variable. Thus wavefunction collapses because we try to analyzes the state of other moment with present classification of states.

When the new state set is a subset of the old one, present information may be kept. But if it is not a subset of the old state set, the measurement can not be done without losing information. We put special emphasize on this point to avoid misunderstanding. Therefore a measurement may be a border-crossing between OE and IE, or it may be a symmetry-breaking in OE. Such clarity for subject is especially important in the research of the foundation of physics because it is always impossible to identify an object to such an absolute clarity that is independent of any observer, i.e., measurement always has its limit. This is not a trivial technical problem. Yet far less than enough attention has been paid to it even since quantum theory was widely accepted. It is usually
considered that the key to the problem of measurement in quantum theory may hide in the further understanding of quantum theory. But actually it may also hide in the further understanding of measurement. Without measurement, the concept of environment can not hold so that observer has no meaning.

In order to measure, we need to have a unit. In some problems, the result of measurement does not change with the adopted unit. But in problems as in fractal geometry [10], it does. Anyway there must be a smallest unit that can not be measured itself. This is the essence of measurement. This is obviously true for all observable quantities, since no quantity can be made up of zeros. We call this smallest unit uncertainty quantum. It is this uncertainty quantum that endows a quantity with real meaning. Here we would like to discuss a thought experiment to show that time is in quantum.

Suppose we have an ideal, infinitely-high-rate camera which can take infinite films in any short time interval. Of course we also have an ideal projector. Then let’s aim at a running dog. If time were not quantized, we would be able to take infinite films of the running dog in any time interval. If then we show these infinite number of films at the normal rate in cinema, the picture on the screen would be motionless. Of course we can see a running dog if we show the films at the same rate as we take them. But because of our persistence of vision (which may be a little bit different from person to person), we lose infinite information of the reality. We can’t know what happens within the interval of persistence of vision. That shows motion is the direct result of our persistence of vision,
which is the uncertainty quantum of time for us human observer in this case.

Thus (the outer) environment is the result of measurement of the observer with the uncertainty quantum to be the unit. Therefore in a sense, the uncertainty quantum determines what environment the observer identifies. The most important property of the uncertainty quantum is that all states or structures within the quantum are totally unknown in present state. (Otherwise we would be able to find structures within it and it would not be the smallest unit.) That means, all structures within the uncertainty quantum are beyond the recognition of the observer in present state. Since the environment of an observer is described with a state set, it is obvious all structures within the uncertainty quantum are not in the state set. Therefore, the complement of the state set composes the uncertainty quantum, which then endows the measurement with real meaning. That is, the IE actually works as the basic measuring units, the uncertainty quantum, for OE to be identified. Now that we have linked together OE and IE with the uncertainty quantum, it can be seen clearly that the opposite time arrow we discussed above is just within the uncertainty quantum, i.e. within the limitation of the observer. Therefore non-local and non-casual events separated in time are connected together by responsible measurement and uncertainty quantum. All states that seem permanently lost in the many-worlds quantum theory are now used not only in measurement as the basic unit, but also in the unfurling of time.

It is also interesting to point out that combining Einstein’s theory of relativ-
ity with our idea of uncertainty quantum, we can also arrive at the conclusion of the opposite arrow of time. In Einstein’s theory, no signal can travel faster than light. Otherwise the arrow of time would be reversed. The related paradox is: if an observer could travel at a super light speed, he might be able to meet and kill himself in the past in his childhood. Though super light speed is permitted in our theory, such a paradox can not hold in our theory. If \( q_l \) is the uncertainty quantum of length (space) and \( q_t \) the uncertainty quantum of time, we may express the speed of light with

\[
c = \frac{q_t}{q_l}
\]

Like Einstein’s theory of relativity, no signals are permitted to travel faster than light, but the light speed, which is always the maximum speed for an observer, may change its value and may be different for different observers. This is because the uncertainty quanta may change. If the uncertainty quantum of time changes greatly enough, we might have to change our definition for past, present and future to such a extent that our past defined in past becomes part of our present. That is, the past, present and future is only the result of measurement with our present uncertainty quantum of time. The smaller the time quantum, the slower the watch of the observer. The larger of the speed of light for one observer, the more non-local correlation to another observer with smaller light speed. Therefore, time’s arrow will never be reversed and there will never be paradoxes as two selves for one person.
The surface of the light cone divides all spacetime into two parts: the spacelike part and the timelike part. From (3) we can see that within the spacelike area, a signal cannot travel farther than a space quantum in one time quantum, while in the timelike area a signal may cross over any space quantum in one time quantum. In the perspective of our framework, to an observer with such a light-cone the timelike area corresponds to smaller time quantum and larger space quantum. (These two are the same, we shall discuss this elsewhere.) Therefore the spacelike area corresponds to OE in our theory and timelike area IE. OE may be called causality area, and IE may be called correlation area. Quantum correlation as in experiments of Bell’s inequality always happens within IE of the observer, where smaller time quantum is needed to see its structure, implicating a super light speed and a reversed arrow of time to the observer.

The idea of uncertainty quantum also has its implication in mathematics. In an infinite measuring process, all structures within the uncertainty quantum are unfolded and realized. Therefore all our limitations in space, time and mass are contained in the corresponding uncertainty quantum. All our limitations are connected, and time arrow is only one way to embody the limitation. The uncertainty quantum is another way. This is the essential ignorance of the observer. Measurement is the process in which a subset of WE is chosen to be the definite ignorance. We know nothing about this ignorance, especially, the number of states in IE. This is exactly where comes the concept infinite. In mathematics the single counting process can be carried on endlessly. This
process is just the unfolding of the points within some basic unit. That’s why the infinity of the points in the whole axis and the infinity of the points in a segment are of the same order. In such linear process there is no loss of information. But in nonlinear problems as we shall discuss in later works, we have to face the breaking of the uncertainty quantum, which always means loss of information and irreversibility.

4 Conclusion

The observer in this research is not necessarily a man. It may be a man with scientific apparatus as his sense organ. It may even be a theoretical system complex enough. In such a generalized framework we show that we can get some new insight into the measurement problem by using a state set description, which is linked with the basic principle of measurement in both classical and quantum physics. This description is necessary in revealing the two opposite directions of the times arrow. We can also understand in this framework why we only sense one time’s arrow. The other arrow of time amazingly hides deeply within the uncertainty quanta, which compose the result of our observation. Although by definition the uncertainty quantum can not be identified, it may have observable effect[11]. We shall show in our later works that locality and quantum correlation can be in a good consistence which is more reasonable in philosophy.
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