

Time, Consciousness, and the Subjective Universe

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By identifying observables in quantum theory as a reference frame for the observer, the relation between time, consciousness, and the structure of our universe is constructed. Because of the peculiar nature of consciousness, namely self-reflexive property, quantum theory fails to provide a consistent description of it due to the separation between the observer and the observed. In order to remove this inconsistency, I will argue that it is necessary to adopt a subjective model of our universe, i.e. it is not the universe that exists, rather; it is the experience of observing the universe that exists. I will then show that the Heisenberg picture with time traveling in reverse offers an accurate description of the proposed subjective universe.

I. INTRODUCTION

The goal of this essay is to discuss the relation between consciousness, time, and the structure of our universe. In particular, I wish to discuss how these ambitious, metaphysical topics can be related using rather simple notions from quantum theory. By identifying an observable as an observer's reference frame, we have a natural physical realization of the Schrödinger and Heisenberg pictures in quantum theory. However, this leads to inconsistency when we consider the phenomenon of consciousness, where the observer and the object being observed are identical: a phenomenon known as 'reflexive self-consciousness'[1, 2]. This inconsistency arises due to the separation between the observer and the object in quantum theory. In order to remove this inconsistency, I propose the subjective universe. That is, identifying the observer with the experience of observing the unitary evolution, instead of the previously assumed picture in which the observer and the object existed separately in the universe and the object was observed in terms of the relative difference between the object and the observer's reference frame. I then argue that, if we assume that what an observer observes is time forwarding, then we have the Heisenberg picture rather than the Schrödinger picture, with time going backwards to provide a correct description of the proposed subjective universe.

There have been numerous interesting suggestions connecting consciousness and quantum theory (for example, see [3–7]). However, unlike previous attempts that have aimed to connect quantum theory and consciousness through the brain, I claim to provide the connection through the identification of observables in quantum theory with the observer's reference frames. Moreover, I do not claim to propose a new philosophical concept of a subjective universe in this essay. Instead, the main strength of this proposal will be to write the conjecture, which has been discussed in philosophy for hundreds of years, in explicit mathematical formulation: that is, using the language of quantum theory.

Much controversy has surrounded the exact nature of quantum theory since its formulation in the early twentieth century. The central issue of the debate has been the subjectivity implied in the axioms of quantum theory, which are closely related to the probabilistic nature of measurement outcomes. Two schools of thought exist in the interpretation of quantum theory. The first has been that current quantum theory is able to produce a prediction with unparalleled high precision, that is, it is an extremely useful practical theory. This is sometimes known as the 'shut up and calculate' type attitude, or the Copenhagen interpretation of quantum theory. The second line of thought argues that observers or measuring devices are also made of particles. Why should they be any different from the observed? Some as yet unknown theory must exist in which this very strange approach of treating the observing system with a special status can be removed. Alternative theories such as the hidden variable theory by Bohm [8] or the many-world interpretation by Everett [9, 10] are proposed along this line of thought. I will show that our proposal of the subjective universe follows neither school of thought and introduces a third possible way.

In sect. 2, I will discuss how consciousness can be discussed within the context of quantum theory and show why reflexive self-consciousness and quantum theory are incompatible at the fundamental level. In sect. 3, I propose the concept of subjective universe in order to remove the inconsistency discussed in sect. 2. I will show that the Heisenberg picture with time going backwards provide a consistent description for the proposed subjective universe model. I conclude with discussion of our proposal in the context of foundations of quantum theory.

II. CONSCIOUSNESS AND QUANTUM PHYSICS

A. Can a computer have a mind?

The research in the field of artificial intelligence, which attempts to imitate and simulate intelligent activities using a machine, has blossomed along with the development of information technology. While the study of artificial intelligence has yielded many insights into intelligent behaviors and a number of useful applications in a wide range, there remains a question whether consciousness or self-awareness could emerge out of a computational system, a view known as strong artificial intelligence. In fact, the physical version of the Church-Turing principle [11] insists that nature, including consciousness, can be perfectly simulated using a computational device. This principle appears quite reasonable considering nature is one big computer performing a computation. Indeed, no counter-example to the Church-Turing principle has been found yet, and it appears that consciousness, as one of the natural phenomena, should be computable just like any other physical system.

At the beginning of the 20th century, physics went through a revolutionary change with the discovery of quantum theory. It is now believed that the universe in which we live is quantum mechanical. Since humans are part of the universe, shouldn't quantum theory provide an explanation for consciousness, a phenomenon experienced by humans? Many people, however, believe that because it is the human brain that is accountable for mental activities, consciousness will be explained when we have a full understanding of the brain through biological means.

Let us pause for a moment and consider what the history of science tells us. It is believed that, as early as the 6th century B.C., Pythagoras noticed that the Earth might have a spherical shape rather than being flat. In the 3rd century B.C., a Greek mathematician, Eratosthenes, is known to have calculated the circumference of the Earth with an error of only about 16%! One of the most important influences on human knowledge came with the theory of Nicolaus Copernicus, who proposed not only that the Earth is not flat, but also that it might not be the center of the universe. Following continued support from Galileo, these scientific achievements have culminated with Newton's gravitation law, which provided an explanation of how the Earth, the sun, and the moon, and our universe operate. Even Newton's gravitational law was replaced a century ago when a young patent clerk provided an explanation of gravity with the geometric structure of space-time. However, notice that all these amazing and truly marvelous achievements took place before a human could go out in space and look at the Earth directly. It was only in 1946, about 60 years ago, that the very first picture of the Earth was taken from space. A picture was taken from an altitude of approximately 100 kilometers by a camera riding on a missile which certainly confirmed the Earth to be round rather than flat, a fact that was predicted some 2,600 years ago. Can we expect a similarity for the study of consciousness? That is, can we delve into the understanding of consciousness using quantum theory, before we have a full understanding of how the brain works, such that we will have direct access to looking at consciousness?

B. Consciousness in quantum physics

Let us consider a dot placed on a one-dimensional line. In order to claim that the dot, which is lying on the line, is either on the right or on the left, there should be a reference point. For example, with respect to the origin, one may say the dot is on the left or on the right. If we consider the reference point to be where the observer is standing, the observer would observe the dot to be either on the left or on the right. It should be noted that if we assume the observer observes the dot to be only either on the left or on the right, i.e., without any other measurement such as the distance of the dot from the observer etc., not only the measurement outcomes are only left or right, so are the possible reference frames. That is, the only possible reference frames the observer could take are to be either on the left or on the right with respect to the dot. Therefore, it can be seen that the degrees of freedom of the object as well as the reference frames of the observer are the same.

This observation is important in considering consciousness in terms of quantum theory. In quantum theory, the state vectors are represented in and evolve in complex Hilbert space, which is not directly observable. It is only when the measurement is made that the outcome yields a real value that is directly observed by an observer. In the case of a qubit, i.e., a two-level quantum system, or a spin 1/2 particle, the eigenvalue outcome is either +1 (spin-up) or -1 (spin-down). Using similar logic to that discussed above, if the possible outcomes are up or down, then there are only two possible reference frames an observer can take, i.e., either up or down, with respect to the spin of the particle. If the observer is in up position, the spin-up particle would appear to be up. However, if the observer is in down position, the spin-up would appear as down to the observer, because the observer is standing upside-down.

However, the particle's spin is not just up and down: its direction is represented in complex vector space. Therefore, the observer's reference frame is not only up and down but also lives in complex vector space just as in state vectors. This is indeed the case with quantum theory, where the observable, i.e., the observer's reference frame, is defined over Hilbert space. Therefore, we see that the reference frame for measuring state vectors is defined over complex

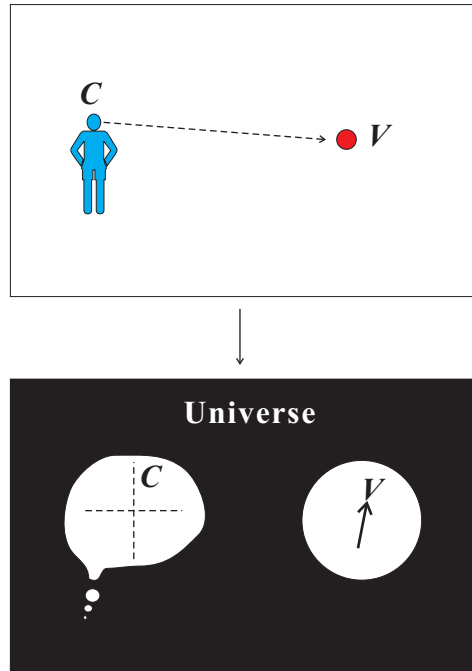


FIG. 1: The natural phenomenon in the top box presents an observer observing a unitary evolution of the physical system in state V with respect to the observable C . If we assume V to be a pure state, quantum theory treats this phenomenon as a completely closed system as seen in the bottom box. That is, not only is V a full representation of the physical system, so is C a full representation of the observer's mental state as far as the natural phenomenon in the top box is concerned.

vector space rather than having real value as in eigenvalues. This leads us to conclude that the reference frame in quantum theory should correspond to the reference frame in the observer's thought, because it is defined over a complex vector space, as opposed to a physical one, such as $+1$ (spin-up) or -1 (spin-down). This may be understood through an example where an observer is stuck in the a two-dimensional surface, yet able to have a reference frame in three-dimensional volume. If this is the case, then the three-dimensional reference frame should correspond to the observer's imagination, i.e., a mental status, because the observer is stuck in the two-dimensional surface. As seen in Fig. 1, the observable can be considered as a coordinate, denoted as C , and the state vector as a vector in the coordinate, denoted as V . However, the coordinate C is defined over complex vector space and only exists as the observer's mental state.

A remarkable aspect of C as the observer's mental state is that the vector C provides a full description of the observer's mental state as far as observing the state vector V is concerned. Just as V is a pure state that is disentangled from other states, the coordinate C is disentangled from all other observables. Since V provides a full description of the physical system regarding the situation in Fig. 1, the observable C not only represents the observer's mental state but also is a full representation regarding the observation of V . This comes in handy because we do not have to worry about how a brain, or any other biological system, is able to create mental activities such that the observer is conscious of measuring the state vector. Therefore, existing quantum theory fully describes the observer's mental state with regards to observing a state vector.

C. Why quantum theory collapses

At a train station, suppose there is an observer sitting in Train A and observes another Train B stationed right next Train A in the opposite lane. The observer observes Train B beginning to move slowly. This observation sometimes causes confusion whether it is Train B that is moving or it is the observer's Train A that is beginning to move. This is because there are at least two possible scenarios for the observer's observation: (i) Train B is moving, or (ii) Train A is starting to move to the opposite direction. In both scenarios, the observer would observe the same phenomenon of Train B moving. Therefore, only after the observer looks at the third object, such as a tree or a platform in the station, the observer is able to tell whether it is Train A or B that is moving. Note that the observer in Train A is observing the movement of Train B due to the relative difference in speed between his own reference frame, Train A,

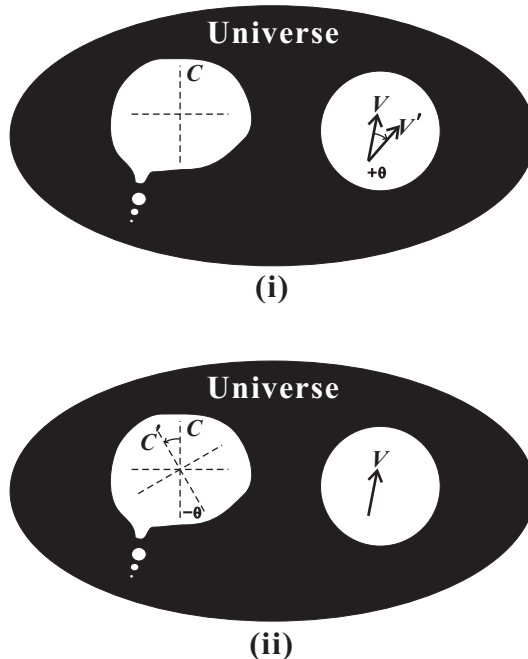


FIG. 2: In the Schrödinger picture (i), the observer's reference frame C is staying still and the qubit represented with the vector V is rotated by θ clockwise. In the Heisenberg picture (ii), it is the observer's reference frame that is rotated counterclockwise by the same amount and the qubit remains still. In both pictures, the observer would experience the same phenomenon.

and the object, Train B. Without Train B, and with nothing else around, the observer in Train A cannot tell whether his train is moving or not moving at all. Consciousness, on the other hand, has one peculiar aspect that is unseen in other situations. That is, the observer is able to observe his own reference frame without any surroundings.

Quantum dynamics yields a similar description as in the example with the two trains. The first case of quantum dynamics is when the state vector, V , is rotated unitarily by (Fig. 2 (i)), and the second case corresponds to when the observer's reference frame, C , i.e., a mental state, is rotated counterclockwise by (Fig. 2 (ii)). In both instances, the observer would observe the vector V being rotated clockwise by θ . The first case corresponds to the Schrödinger picture, and the second to the Heisenberg picture, of quantum theory.

We discussed that consciousness has one peculiar aspect where the observer is able to observe its own reference frame. As shown in Fig. 3, let us consider the case where there is no state vector but only an observable, i.e., an observer is observing his own mental state, reflexive self-consciousness [1]. What does it mean for an observer to observe his own reference frame? Given a qubit, an observer may choose to measure it on some basis, i.e., choose to measure the qubit within certain reference frame. However, note that choosing the basis, i.e., having a certain reference frame, can be done without actually possessing a qubit. In this case, one can see that the measurement basis, i.e., the vector C , is playing the role of both a state vector, because it is being observed, and an observable, because it serves as a reference frame. Moreover, not only can an observer observe his own reference frame, but he can also change the choice of measurement direction when there is no qubit. With regards to this change, quantum theory should provide an explanation, if we assume the universe is quantum mechanical and consciousness is part of the universe.

As discussed, quantum theory provides two approaches for its dynamics. In the Schrödinger picture, the coordinate C is unitarily rotated clockwise because it is the system that is being observed (see Fig. 3 (i)). However, in the Heisenberg picture, C is an observable which is rotated counterclockwise (see Fig. 3 (ii)). Therefore, one can see that the two approaches do not yield the same observational phenomenon, i.e., C is rotated into two different outcomes. This is because in the case of consciousness, which is unprecedented, the vector C plays the role of both a state vector and an observable. Therefore, unlike as with other physical phenomena, quantum theory collapses and fails to provide a consistent description of certain natural phenomenon of consciousness [12].

This particular distinctive property of consciousness can be explained in terms of computability. The physical version of the Church-Turing principle conjectures that it is possible for a quantum computer to perfectly simulate the whole of nature. This thesis appears quite reasonable, since the time evolution of nature may be considered as a process of computation, and if we have a sufficiently large quantum computer, then it could simulate the whole of

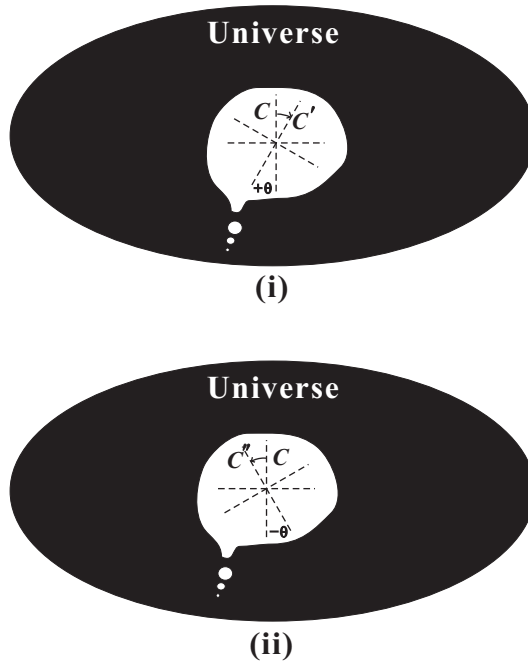


FIG. 3: Reflexive self-consciousness[1]. In case of self-observation in cognitive science, the vector C plays the role of both a reference frame as well as an object being observed. In the Schrödinger picture (i), the vector C , being an object, is rotated clockwise and in the Heisenberg picture (ii), the same vector, being the reference frame, is rotated by $-\theta$. In both pictures, they do not yield the same observational phenomenon.

nature. There are two underlying implications in the statement of the Church-Turing principle: Firstly, it assumes that human consciousness is a part of the whole of nature, and secondly, a quantum computer is assumed to work in both the Schrodinger and the Heisenberg pictures. The second implication suggests that *it is impossible to build a quantum computer which does not satisfy both pictures!* However, it has been argued that consciousness cannot satisfy both pictures. This suggests that it is not possible to build a quantum computer that can perfectly simulate consciousness and, therefore, it yields to be a counter-example to the Church-Turing principle [13].

III. SUBJECTIVE UNIVERSE AND TIME

A. Does the moon exist only when someone is looking at it?

Puzzled and frustrated with the hint of subjectivity and the probabilistic nature of quantum theory, Einstein asked his colleague Abraham Pais the famous question as to whether the moon exists only when someone is looking at it. This contradicted his belief in objective reality. In ‘Discourse on the Method’, Descartes introduces a method that initially starts by doubting everything around him. Then he wanted to ask what can be certain, that is, absolutely certain such that it can never be doubted. He then came to a conclusion that while everything else could possess non-zero uncertainty about its existence, at least a thought itself can never be the case. This led to the well known statement, “I think, therefore I am”. This seemingly simple and innocent looking statement laid a foundation for a modern philosophy. When we look at an apple and say “it is a red apple”, the redness of the apple is what we observe and may not necessarily be the actual color of the apple. When we say the apple is red, we are actually saying the apple ‘as we observe’ has a red color. Scientific laws are derived based on what we observe or experience. Even experiments, as objective as they may seem, are what we, as observers, experience. Any attempt to have a completely objective description of nature is doomed to failure. Physical laws provide us with not about the law of objects, such as the moon, the Earth, or elementary particles etc., but the way the we, as observers, observe or experience them.

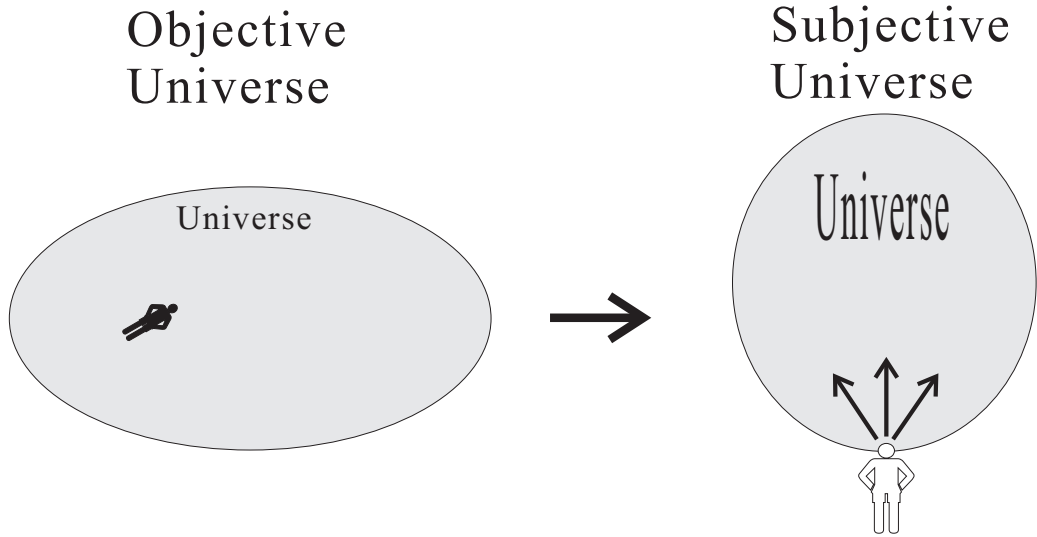


FIG. 4: Objective and Subjective Universe models. In the objective universe model, the observer and the object are contained within the universe and they are separated. In the subjective universe model, it is not the universe that exists as in the objective model, instead, it is only the experience of observing the universe that exists.

B. Subjective Universe

The problem of describing self-observation comes from the fact that we are used to separating the observer and the object being observed. This assumption then explains that the observer is observing the object in terms of the relative difference between his own reference frame and that of the object. However, this seemingly very reasonable assumption runs into problems when we want to describe the experience of observing the change of one's own reference frame as I have shown above. In order to remove the dilemma of describing self-referencing, the observer has to be defined with the experience itself (see Fig. 4). In [14, 15], this argument was put into a conjecture as follows:

Subjective Universe: Being is the experience of observing the evolution θ and its association with time t .

It can be seen that the conjecture removes the assumption of separating between the observer and the observed. In sect. 1, I discussed that there are two lines of thought in terms of the foundations of quantum theory. The people who tend to side with Bohr claim that quantum theory provides the most precise description of what an experiment will produce. While this may sound reasonable, axioms of quantum theory put the observer in a distinctive place from the object being measured. This is puzzling for people who believe science should provide us with a law that describes the objective reality of the universe. I have discussed the fact that how physical law derived solely from our subjective experience has a fundamental limitation in that it will always remain perfectly subjective. Our conjecture derived from the resolution of the fundamental contradiction when describing consciousness insists that not only the current quantum theory, being subjective, is practically useful, but is logically and philosophically correct. That is, the observer should indeed have special status. Not only is the observer special, but the observer, i.e., the experience of observing as outlined in the conjecture, is all that exists as far as science is able to tell.

When we look at the history of human knowledge, we can roughly divide it into two periods, i.e., before and after Copernicus. Before Copernicus, many people thought the Earth was flat and was the center of everything. Then came a revolution solidified by Copernicus, Newton, Einstein, and many other remarkable scientists, who realized that the Earth was neither flat nor was it the center of the universe. The conjecture described above is attempting to overthrow the second period. However, it does not wish to claim that the Earth is the center of the universe, but that the observer is. This line of thought has been discussed by philosophers for centuries: I have already discussed the argument of Descartes. Philosophers such as Berkeley, Kant, Schopenhauer, and Heidegger also followed similar lines of thought. I have shown that separating an observer and an object being observed runs into a contradiction. Therefore, it is not the observer and the object that exist separately inside the universe: the experience of observing the universe should define the observer. For example, it is not the universe that has existed for billions of years, but the experience of observing the universe to be billions of years old exists. However, it should be noted that the conjecture

does not necessarily mean that what we experience and observe is all hallucination. Instead, the conjecture would fit better into Heidegger's concept of existence, *da-sein*, i.e., the physical world and the observer are inseparable.

C. Time in the Subjective Universe

In this section, I wish to discuss which physical description correctly describes the conjectured subjective universe. I showed that not only did the same vector evolved into two generally different states, but also the evolution of the vector C is physically sensible in neither of the two approaches in quantum dynamics. Using the postulate of identifying the observable as observer's reference frame, we were able to impose a physical meaning on the two equivalent approaches of quantum theory. However, when it is the observer's own mental state that is evolving, it is not easy to imagine how an observer is able to observe it. Let us assume that the vector C is pointing z -direction in the $x - z$ plane with the unitary operation of rotation about y -axis, i.e., C evolves under $U = \exp[-i\sigma_y t/2]$ in the Schrödinger picture ((i) of Fig. 3). And the final state of C would be rotated by θ after time t , which I will write as $\theta(t)$. The difficulty of obtaining a physically sensible picture with this evolution is that in order to experience this unitary evolution, the observer needs to be in another reference frame, say $\theta'(t)$. However, C itself is the observer's mental reference frame and there cannot be another reference frame. Similarly, in the second approach ((ii) of Fig. 3), C evolves under $U^\dagger = \exp[i\sigma_y t/2]$. The vector is being rotated counterclockwise and is in $-\theta(t)$. In this case, for the observer in the reference frame of $-\theta(t)$, there needs to be an additional vector in $\theta''(t)$ in order for him to observe the evolution of C . Again, this is not possible because $-\theta(t)$ is not only the observer's mental reference frame but also the object that is to be observed. Therefore, in order to have a satisfactory picture of the observer observing his own reference frame's evolution, he needs another reference frame or another vector.

Let us make an assumption which will be helpful in the following argument. It is stated as follows:

Postulate: What an observer observes or experiences must be time forwarding.

Note that we are only assuming that the observer's experience is time forwarding and not necessarily the whole system, i.e., including the physical system and the observer, is time forwarding. I now proceed with our argument to consistently describe self-observing consciousness. Let us re-consider the evolution of C under the Heisenberg picture. Note that for the unitary operation in Heisenberg picture, it is possible to change the signs of t and σ_y while keeping the whole unitary operator the same, that is $U^\dagger = \exp[-i\sigma_y(-t)/2]$. This corresponds to the vector evolving to $+\theta$ while t is going to the minus direction compared to the previous Heisenberg case wherein the vector evolved to $-\theta$ with time going forward. In this case, we note that the observer cannot be in the reference frame $\theta(-t)$ because from the assumption that what the observer observes or experiences is only time forwarding. If the observer is in the reference frame that is moving backward in time, he would observe everything going backward in time. However, from the assumption I made, this is not possible. We therefore see that the observer cannot be in the reference frame. Since the observer cannot be in the reference frame $\theta(-t)$, this picture fits well to describe our criterion to describe self-observing consciousness. That is, rather than the observer being in the reference frame, the experience of θ defines being. Also note that although we are taking the Heisenberg picture with time going backwards, there is no problem for the observer's experience is time forwarding since we are identifying the observer with the experience θ and the observer is not in the reference frame as argued.

We may consider the same trick with the Schrödinger picture evolution, that is, by putting minus signs for both time and σ_y . But in this case, it still requires an additional observer's reference frame because the observer who is in the reference frame with time forwarding would simply observe θ in $+t$. This is similar to the way an electron in the negative energy would appear as a positron in the positive energy to an observer who is also in the positive energy. Therefore, in the Schrödinger picture, this new view still requires an additional reference frame and is not satisfactory. I therefore conclude that the Heisenberg picture with time going backwards provides a consistent description of the proposed conjecture of subjective universe.

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