Does Observation Create Reality?

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Abstract

It has been suggested that the locality of information transfer in quantum entanglement indicates that reality is subjective, meaning that there is an innate inseparability between the physical system being observed and the conscious mind of the observer. This paper attempts to outline the relation between macroscopic and microscopic worlds in the measurement process in regards to whether observation creates reality. Indeed, the Maxwell's demon thought experiment suggests a correlation between a microscopic (quantum) system and a macroscopic (classical) apparatus, which leads to an energy transfer from the quantum vacuum to the physical world, similar to particle creation from a vacuum. This explanation shows that observation in quantum theory conserves, rather than creates, energy.

Key Words: Maxwell's Demon, Reality, Measurement, Entanglement.

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Introduction

Ever since quantum theory was first introduced about a century ago, its exact nature has generated much discussion. The Copenhagen interpretation, which is a standard way of understanding the theory, separates the object and the subject, thereby shifting previous scientific practices. The idea of finding the idealistic objective reality gave way to the pragmatic approach of an interplay between the observer and the object.

According to general understanding, there are two main aspects in quantum theory (Figure 1), namely,

1. deterministic
2. probabilistic

The first aspect is in line with traditional scientific studies in that it is objective, i.e., it does not involve the necessity of the observing party. However, the second aspect has led to disagreement and confusion. Unlike the first, it inherently involves the need of the observing party and, therefore, contains a certain element of subjectivity. As subjectivity has not generally been part of standard scientific practices, researchers often attempt to minimize or undermine the probabilistic and concentrate on the deterministic.

Although this appears at first glance to be more of a science fiction, if reality could change depending on observation, could it not then be created from nothing? Pascual Jordan, a physicist who also contributed significantly to quantum theory, mentioned a similar idea (Jordan, 1974):

> *Observations not only disturb what has to be measured, they produce it.*

In this paper, the relationship between reality and observation is examined. In particular, it will be argued that the observation as noted in the Copenhagen interpretation does not create reality but instead *transfers* energy from the quantum vacuum filled with negative sea to the macroscopic physical world.

In section 2, the subjective nature of physical reality that is implied in entanglement is reviewed. The negative entropy shown in Maxwell's demon is examined in the context of quantum measurement where there exists a transfer of energy between microscopic and macroscopic systems. The relation of Maxwell's demon to the discussion of gravity is provided in section 4. The paper concludes with some remarks on its implications.

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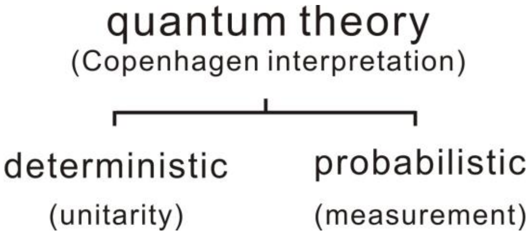


Figure 1. Quantum theory, particularly the Copenhagen interpretation, contains not only deterministic and unitary aspects that pertain to microscopic behavior, but also probabilistic aspects that connect microscopic and macroscopic worlds.

Physical Reality

In 1935, unsatisfied with the subjective description of quantum theory, namely, the involvement of observation and probabilistic nature, Einstein, Podolsky, and Rosen (EPR) introduced a protocol which may indicate the insufficiency of quantum mechanics (Einstein *et al.*, 1935). Subsequent innovative Bell-type inequalities (Bell, 1964; Clauser *et al.*, 1969) and delicate experiments (Aspect *et al.*, 1982) have strongly suggested non-local property to be an integral part of quantum theory.

Conversely, there have also been aspects of locality observed in quantum entanglement, specifically that there is no superluminal transfer of information using an entangled system (Ghirardi *et al.*, 1980). This is rather odd considering that particles (i.e., objects) are able to communicate faster than light, while observers (i.e., subjects), who are thought to be made of particles or objects, are not able to do the same. To explain this predicament, it was suggested that reality should be subjective, meaning that existence corresponds to *meaningful* data (Song, 2020).

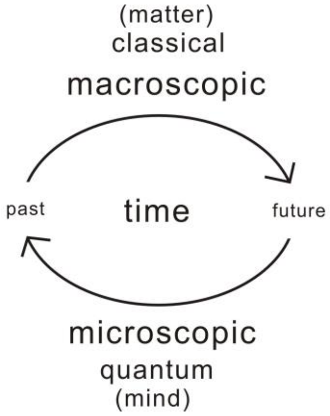


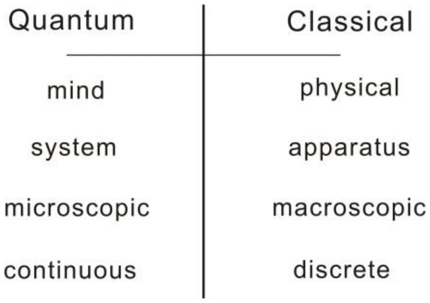
Figure 2. In cyclical time, physical matter is moving forward in time while the mind (quantum reference frame) is moving backwards.

The idea of meaningful versus meaningless data can be explained with an example of an entangled state as follows: $\frac{1}{\sqrt{2}}\left(|00\rangle+|11\rangle\right)_{AB}$. If Alice measures her qubit A, this then prepares the qubit at Bob's end. The traditional understanding in objective reality would be that the prepared state (or reality) is a pure state, but, to Bob, the reality is hidden. That is, the physical reality of the qubit B is prepared right after Alice measures her qubit A, but this (objective) reality is not revealed to Bob; therefore, there exists nonlocality but there is no instantaneous information transfer.

However, in terms of subjective reality, nothing has actually traveled faster than light since reality corresponds to not only data but data with meaning, namely information. To Bob, the physical reality would correspond to the pure state, with proper information obtained about both Alice's choice of measurement and the outcome. In fact, in (Einstein *et al.*, 1935), EPR outlined the physical reality, i.e., something that can be seen, touched, etc., as follows:

> *If, without in any way disturbing a system, we can predict with certainty (i.e., with probability equal to unity) the value of a physical quantity, then there exists an element of reality corresponding to that quantity*

Therefore, EPR's criteria of reality and conditions of locality remain constant at the expense of changing reality from objective to subjective.



Quantum	Classical
mind	physical
system	apparatus
microscopic	macroscopic
continuous	discrete

Figure 3. Quantum aspects as they are defined in complex vector space are associated with the observer's continuous conscious mind and microscopic behavior while classical corresponds to the macroscopic world that is discrete and apparatus in the case of measurement.

In (Song, 2020), in order to specify the subjective reality, cyclical time was adopted such that time moving forward corresponds to the macroscopic, classical, or physical world, while time going backwards corresponds to the microscopic quantum world. In this way, the data or physical part is attached with its conscious meaning of negative sea (Figure 2).

When discussing the subjective reality model, it is often assumed that the classical system is discrete while the quantum part is continuous, that is, unitary transformations occur in state evolution. As discussed by Plato and Aristotle, the mind can imagine idealistic objects, such as a perfect circle or continuity, while the physical world is thought to comprise discreteness. For example, no matter how accurately a measurement in the physical world is taken, it will never be completely free of an error. This illustrates a clear distinction between the idealistic mind and the imperfect physical world.

Microscopic and Macroscopic

The relationship between observation and reality can be considered through the lens of the following three steps:

Step 1: Separate quantum and classical systems.

Step 2: Observation involves correlation between quantum and classical worlds.

Step 3: As seen through Maxwell's demon, there is energy transfer from quantum to classical realms.

The first step attempts to clearly distinguish between the classical and quantum systems. That is, both macroscopic and microscopic worlds are fundamental and exist with equal importance, rather than one being an approximation of the other. Unlike the classical space, quantum states are defined in a complex vector space, to which an observer does not have a direct access (Figure 3). Following this line of thought, in (Song, 2007), the observables were identified via the observer's mental reference frame. In terms of a subjective reality model, this step implies a clear distinction between the mind (i.e., quantum systems) and physical or classical systems.

The next step follows common practice in quantum measurement, namely the semiclassical treatment. While the system being measured is quantum mechanical, the apparatus is considered a classical system and the measurement assumes entanglement between these two realms. Although the name semiclassical implies that something is incomplete or insufficient, as discussed in the first step, we consider this interaction between the classical and quantum as fundamental and full.

If we use the previously discussed terms specifically in regards subjective reality (Figure 2), the semiclassical treatment of the measurement process involves entanglement between invisible mind and tangible matter. Niels Bohr, one of the central proponents of the Copenhagen interpretation, also commented on the possible tie between the observer and the object as follows (Bohr, 1928; Zinkernagel, 2016):

> *... an independent reality in the ordinary physical sense can neither be ascribed to the phenomena nor to the agencies of observation.*

In 1867, Maxwell ruminated (Maxwell, 1871) on a demonic being that could potentially violate the second law of thermodynamics by extracting work or energy cyclically. Szilard then imagined (Szilard, 1929) a simplified version of Maxwell's demon with a single molecule gas. Later, it was demonstrated that this work or energy extraction does not violate the second law of thermodynamics because there must be a compensating energy dissipation in erasing the memory of the demon (Landauer, 1961; Bennett, 1982). The quantum version of Maxwell's demon has also been discussed and analyzed by a number of authors (Lloyd, 1997; Vedral, 1999; Kim *et al.*, 2011; Cottet *et al.*, 2017).

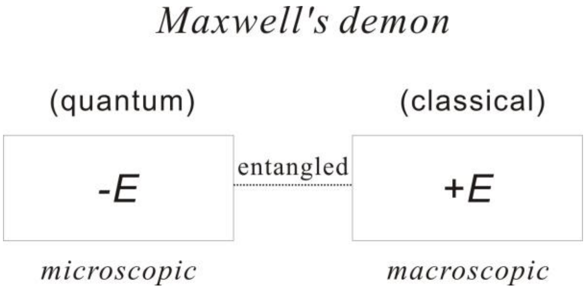


Figure 4. Observation of the idea of Maxwell's demon shows the work extraction from the system. This may also be considered in the process of measuring entanglement between quantum and classical realms.

As shown in Figure 4, one may consider the work extraction in the Maxwell's demon discussion as the energy extraction from the (quantum) system to the classical (apparatus) realm (also see Elouard *et al.*, 2017). That is, the decrease of energy in a microscopic system is compensated by the increase of energy in the physical world (i.e., work extraction) (Figure 5) which may be summarized in terms of subjective reality as follows:

Proposition: There is an energy transfer from the negative sea (mind) to the physical world in quantum measurement.

In (Cerf *et al.*, 1996), the negativity of conditional entropy was observed in quantum entanglement and the authors discussed the correlation between qubit and anti-qubit, i.e., a qubit moving backwards in time. We may consider the entangled quantum and classical realms in similarly, such that the quantum part is interpreted as moving backwards in time. Interestingly, there are similar themes seen cases of subjective reality where the continuous unitary evolution of the quantum reference frame of the observing party evolving backwards in time corresponds to the observer's consciousness.

Inter Subjective Gravity

One of the biggest confusions regarding quantum theory has been the sometimes dubious division between microscopic and macroscopic worlds. This is because the precise boundary between the two has not always been clear, particularly with the advancement of quantum technology, when the quantum states began to be realized as physical systems that continued to increase in size. Indeed, quantum theory does not strictly prohibit a larger system to be in a quantum state, such as a superposition of 0 and 1.

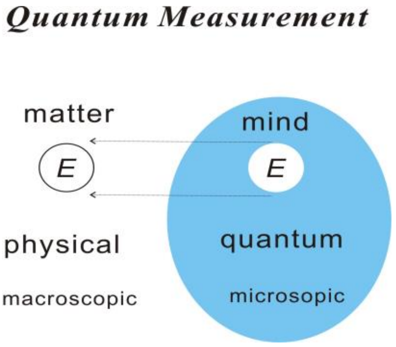


Figure 5. In a subjective reality model, the Maxwell's demon discussion implies that there is an energy transfer from invisible mind to the physical world.

Indeed, a consistent understanding between quantum theory and gravity has always been important in physics. This is to say that while quantum theory explains the microscopic world (e.g., elementary particles) very well, gravity deals with macroscopic objects, such as the moon or galaxies._This is not so satisfactory considering that macroscopic objects such as the moon are considered to be composed of microscopic objects.

As previously discussed, quantum theory not only contains the deterministic part, but the measurement aspect as well. In fact, the measurement is what connects the microscopic and macroscopic systems. Therefore, in order to have a consistent understanding of the relationship between quantum theory and gravity, one must pay close attention to the measurement aspect of quantum theory since it deals with both the micro and macroscopic worlds.

General relativity shows a relationship between space-time and mass. Indeed, as Wheeler famously summarized (Wheeler, 2000), "*Mass tells space-time how to curve, and space-time tells mass how to move*', it is often thought__that mass curves spacetime such that it generates gravitational phenomena. However, the relationship between mass/energy and space-time as specified in relativity may be viewed a bit differently. That is, rather than mass or energy curving space-time, it is the curved space-time that generates or *creates* mass.

The relationship between thermodynamics and gravity has been discussed by a number of people (Jacobson, 1995; Padmanabhan, 2010). In particular, in (Verlinde, 2011), it has been suggested that gravity is an emergent phenomenon, or an entropic force, which is in line with what is stated above. That is, the process of observation is understood as a thermodynamic system, a quantum part, providing a gravitational force onto a physical world as seen in Figure 6. .

In fact, the subjective nature of reality begs the question: if the reality of universe is indeed subjective, why do we perceive so many of the same things? For instance, why does gravity appear to commonly apply to many individual persons? Or, why is it that logical processes in mathematics are shared by many people?_In fact, gravity may be the rule that arises out of a *shared* consciousness of individual persons.

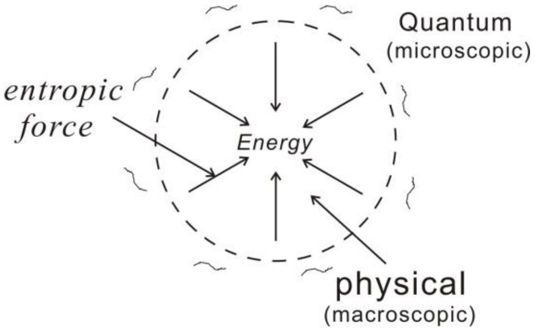


Figure 6. The proposed energy transfer in quantum measurement is similar to the entropic force that is generated from a quantum thermodynamic system to the classical world.

Remarks

Ever since the ancient Greeks, such as Plato and Aristotle, discussed the issue of idealism versus pragmatism, science has struggled with its approach to describing tangible physical nature, particularly with the birth of quantum theory. The confusion is certainly understandable since science has mostly attempted to provide an objective description of physical reality, i.e., independent of who is observing the physical system, if there is even an observer. However, the Copenhagen interpretation, which provided arguably the most economical and simplest description of reality, suggests that reality may change depending on individual observations.

Indeed, in quantum theory, there began a debate of if science provides an idealistic, objective description of nature or a mere interplay between the observer and the observed nature. If the reality of physical systems is observation-dependent, could the very existence of the object also depend on the observer too? This is certainly a reasonable speculation, as quantum theory broke the centuries-old tradition in science.

In this paper, we have argued that observation in quantum theory transfers energy (or mass) from the vacuum of negative sea, which represents the mind of the observer, to the observed physical world. This is interesting in a sense that what is seen results from what is unseen. It may also be said that what is observed physically was already determined in a sense that in the negative sea the time is assumed to move backwards.

In studying quantum theory, it has often been the case that only its deterministic aspect is investigated while its measurement part is minimized and often underrated as a philosophical discussion. However, quantum measurement may be a central part in the scientific description of nature since it connects the microscopic and macroscopic realms. Moreover, quantum measurement may shed light on interconnecting quantum theory and general relativity in the sense that while quantum theory implies the subjective nature of our experience, relativity provides an objective aspect, namely, a rule independent of the chosen coordinate system or the observer's reference frames. This may help us understand why there are commonly shared parts while individual persons experience nature subjectively.

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