

Critique of “ *Quantum Enigma, Physics encounters Consciousness* ” by Bruce Rosenblum and Fred Kuttner

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Introduction

When discussing the quantum theory and its interpretation in physics, Bohr often emphasized the importance of describing fully the experimental apparatus, and selecting the proper words to describe the observations. In 1948 he put it as follows [1]:

*Phrases often found in the physical literature as ‘disturbance of phenomena by observation’ or ‘creation of physical attributes of objects by measurements’ represent a use of words like ‘phenomena’ and ‘observation’ as well as ‘attribute’ and ‘measurement’ which is hardly compatible with common usage and practical definition and, therefore, is apt to cause confusion. As a more appropriate way of expression, one may strongly advocate limitation of the use of the word *phenomenon* to refer exclusively to observations obtained under specified circumstances, including an account of the whole experiment.*

Unfortunately, these admonitions are generally ignored by the authors of *Quantum Enigma (QE)* [2], and as a consequence this book will cause plenty of the confusion predicted by Bohr. In the following section, I will quote selected paragraphs that contain what I consider to be some of the more outlandish statements which I found in this book, followed by my critique.

In support of this critique, I include in the last section some relevant quotations from Bohr, Einstein, Heisenberg, Bell and other prominent physicists, concerning quantum mechanics and the measurement process. These quotations contradict many of the claims and unsupported assertions made in this book about the interpretation of quantum theory. In particular, all these physicists *deny* the supposed role of *consciousness* in physics, for which there isn't any experimental support whatsoever. But the claim that consciousness plays a role in quantum mechanics (“our bias”) is the underlying message which the authors of QE would like to implant on their readers.

The authors of QE also offer support for their claims with quotations from prominent scientists. For example, Martin Rees, who is the Astronomer Royal and current president of the Royal Society in London, is quoted as saying (ref. [2] page 193):

*In the beginning there were only probabilities. The universe could only come into existence if someone observed it. It does not matter that the observers turned up several million years later. The universe exists because we are aware of it*¹ (ref. [2] page 193).

In contrast, Murray Gell-Mann, who won a Nobel Prize for his fundamental contributions to particle physics, is quoted in QE as saying that

The universe presumably couldn't care less whether human beings evolved on some obscure planet to study its history; it goes on obeying the quantum mechanical laws of physics irrespective of observation by physicists (ref. [2] p.156)

The authors of QE response is that “ in talking about classical physics, Gell-Mann's *presumption* [my italics] would go without saying (ref. [2] p.

¹The authors of QE do not give sources for the numerous quotations in their book. Therefore, I asked Martin Rees where he had made this statement and he responded: “I am perplexed by the quote. It seems rather 'Wheelerish' – not at all the sort of thing I would have said.”. Apparently this quotation was inserted by an editor as a caption to a figure in an article that Rees had written for the New Scientist (August 6, 1987). Indeed, it turns out that this figure is a copy of a drawing made by John Wheeler which also appears on page 200 of QE, and that the caption paraphrases Wheeler's words in a script entitled “Law without law”. The original caption starts with “ The universe viewed as a self excited circuit”. Apparently, Wheeler was in a playful mood, because he asserted that “caution: consciousness has nothing whatsoever to do with quantum processes” (see quotation at the end of the next section)

168). But Gell-Mann is talking about quantum mechanics which governs *all* the fundamental process in our the universe. The examples discussed in QE are concerned with *elementary* or *single* quantum processes, and the authors are unaware that there is a distinction in analysing such processes and the multiple quantum processes that occur in macroscopic size systems like tables, stars and galaxies. ²

In fact, it is the statement made by Gell-Mann and not the one attributed incorrectly to Rees (see footnote 1), that represent the generally accepted view that *all* processes in the universe evolve in accordance with the laws of quantum mechanics *without* any need whatsoever of conscious observers. In cases where classical mechanics is adequate it is regarded as an approximate theory.

John Bell, who is regarded as having made one of the most significant modern contributions to our understanding of quantum theory, remarked that

I see no evidence that it is so [that the cosmos depends on our being here to observe the observables] in the success of contemporary quantum theory. So I think it is not right [my italics] to tell the public that a central role for conscious mind is integrated into modern atomic physics. Or that ‘information’ is the real stuff of physical theory [5]

I think the experimental facts which are usually offered to show that we must bring the observer into quantum theory do not compel us to adopt that conclusion. [6]

²For example, consider the evolution of a star like the sun. This evolution is primarily based on quantum phenomena, with classical gravitational forces primarily providing the confinement for the atomic process. Thus the production of energy is due to nuclear reactions governed by quantum processes in the interior of the star, which requires also the phenomenon of quantum tunneling, the emission of radiation, which is governed by the laws of quantum field theory, and the eventual collapse of a star like the sun into a white dwarf or neutron star, which depends on the quantum mechanical degeneracy pressure of electrons or neutrons [3]. Even the explosion of more massive stars into supernovas gives rise to quantum nuclear processes leading to the emission of neutrinos. Since the start of the Big Bang all these processes have been going on without the need of any “observers”, conscious or otherwise. The most striking evidence of the Big Bang is the low temperature black body radiation which is created in the early universe by quantum process , without any observers around [4]

For a long time I have argued along the same lines that I found recently in an article by A. Leggett [7] , a Nobel prize winner who has given considerable thought to the quantum measurement paradox,

...it may be somewhat dangerous to ‘explain’ something one does not understand very well [the quantum measurement process] by invoking something [consciousness] one does not understand at all!

But instead of “it may be dangerous”, I would say “it is nonsense”.

These last three comments firmly contradict the central claims of the authors of QE concerning a supposed role for consciousness in physics ³

Selected quotations from QE, followed by my critique

Each quotation from QE listed below is written in typewriter style, and is identified by the page number (p.n) and the line number counted from the bottom (b.n) or the top (t.m) of the page. My criticisms follow after each quotation.

`This is a controversial book. But nothing we say about quantum mechanics is controversial. The experimental results we report and our explanation of them with quantum theory are completely undisputed (p.3 t.1)`

Invariably, however, experimental results are reported in this book in a very sketchy and innacurate manner, which leads to the confusion predicted by Bohr (see Introduction). Moreover, as will be shown below, the statement that “our explanation of them [the experiments] with quantum theory is undisputed” usually turns out to be false.

`That physics has encountered consciousness cannot be denied (p.4 b.13)`

³I share Steve Hawking’s impulse “to reach for my gun” (ref. [2], p. 120) whenever Schrödinger’s cat story is told. This cat story is notorious. It requires one to accept that a cat, which can be in innumerable different states, can be represented by a two state wavefunction, a bit of nonsense which Schrödinger himself originated. It is claimed that Schrödinger never accepted the statistical significance of his celebrated wavefunction

Presumably Bohr, Heisenberg, Einstein, and the other great physicists I quote in this critique have been living in denial. Only very few prominent physicists, e.g. E. Wigner, have argued for a role of consciousness in the measurement process. But such exceptional cases do not justify ignoring the warning of Bell “ that it is not right to tell the public that a central role for consciousness is integrated into modern physics”

The quantum enigma conventionally called the ‘ ‘measurement problem’ ’, appears right up front in the simplest quantum experiment p.5 t.9

The measurement problem can be summarized as the question why macroscopic detectors like a Geiger counter or a photographic plate, which are ultimately made of atoms, are never found in a *superposition* of quantum states. The authors of QE claim that *consciousness* is what destroys this superposition. But if there are several observers, whose consciousness is responsible for this collapse of superposition? If both authors of QE look at the *same time* at a photographic film recording an atomic event, who “caused” the collapse of superposition? And what happens when you have a thousand observers, as is often the case in current high energy physics when zillions of events are observed?

Try summarizing the implications of quantum theory, and what you get sounds mystical... To account for the demonstrated facts, quantum theory tells us that an observation of one object can instantaneously influence the behaviour of another greatly distant object - *even if no physical force connects the two*. Einstein rejected such influences as ‘ ‘spooky interactions ’ ’ but they have been now demonstrated to exist. (p.12 b.14)

The “facts” that have been demonstrated are *correlations* between distance particles which are predicted as a consequence of *conservation laws*. For example, due to conservation of energy and momentum in a two particle scattering event, the observation of the momentum of one of the scattered particles determines the momentum of the other scattered particle. This correlation is expected both in classical and in quantum theory, and there is nothing “mystical” about it. There are also correlations of polarizations of

entangled photons which are predicted by quantum theory that have been confirmed by experimental observation. These correlations are consequences of the *conservation law* of angular momentum. The claim that Einstein *rejected* these correlations is false (for some quotations of his views of quantum theory see section II).

For example, according to quantum theory, an object can be in two or many places at once - even far distant places. Its existence at the particular place it happens to be found becomes an actuality upon its (conscious) observations. (p.7 b.9)

Both statements are false. Quantum theory is a theory that predicts the probability of observing physical attributes of a particle like position and momentum. The probability of finding a particle in “two places at once” is *always* zero. The question can be asked as to where a particle is located in between observations, but this question is *metaphysical*, and lies outside the realm of scientific inquiry. The claim that it requires *consciousness* to make the location of an object an “actuality”, which is repeated like a mantra throughout QE, is not supported by any evidence, and is demonstrably false.

But they [our physics colleagues] will find nothing *scientifically* wrong with what we say. The physics facts we present are undisputed (p.13 b.12)

This claim, which is being promoted in QE to an unsuspecting public, is untrue, as will be demonstrated here in many examples.

The waviness⁴ in a region is the probability of *finding* the object in that region. Be careful—the waviness is not the probability of the object being there. There is a crucial difference! The object was not there until you found it there. Your happening to find it there *caused* it to be there. This is tricky and the essence of the quantum enigma. (p.75 b.12)

⁴This name was introduced by Bell, and refers to the absolute square of the wavefunction

The muddled second half of this statement is incorrect. The absolute square of the wave function gives the probability for the outcome of an experimental observation such as the localization of an atomic particle. A particle can be localized by an appropriate recording device, a Geiger counter, a photographic plate, etc., independent of any particular human observer. One need only to realize that different observers who examine such a recording all reach the same conclusion about the region of localization to see that the remark “your happening to find it there *caused* it to be there ” is nonsense. An observer does not *cause* the occurrence of an atomic event. This is like believing that you can bend spoons with your mind. No one has given evidence for such effects.

The authors of QE claim that

In quantum theory there is no atom in addition to the wavefunction of the atom. This is so crucial that we say it again in other words. The atom's wave-functions and the atom are the same thing; ‘the wave function of the atom’ is a synonym for ‘the atom’ (p.77 t.6)

Since the wavefunction is synonymous with the atom itself, the atom is simultaneously in both boxes. The point of that last paragraph is hard to accept. That is why we keep repeating it. (p.103 t.3)

In other words, since matter consist of atoms, presumably while reading this nonsense you are sitting on a chair made up of wavefunctions (do you also feel the vibrations?). Of course, the wavefunction of an atom is not a synonym (having the same meaning) for the atom. The claim for such a *synonym* is nonsense. Atoms have mass, charge, total spin and energy levels, which are *invariant* properties, while the wavefunction describes the evolution of its dynamical variables. According to quantum theory, the square of the wave function gives the probability that the measurement process yields allowed values for a set of commuting variables. For this purpose it is necessary to study an ensemble of atoms which initially are prepared under identically the same physical conditions. This is fundamentally different from claiming that the wavefunction is *synonymous* with the atom itself. The probability of observing an atom *simultaneously* at two different locations, by an actual measurement, is always *zero*. Hence, it is false to claim that the atom “is *simultaneously* in both boxes”.

Accordingly, before a look collapses a widely spread-out wavefunction to the particular place where the atom is found, the atom did not exist there prior to the look. The look brought about the atom's existence at that particular place - for everyone

This is a powerful "look" indeed, but again, this false. In spite of Bohr's repeated warning of the importance of carefully choosing appropriate language to describe the observation of atomic events, this warning is again ignored here. Statements like "before a look collapses ... a wavefunction" or "the look brought about...the atom's existence" do not make any sense or have any meaning whatsoever. According to the description of some of the founders of the quantum theory who are quoted in the next section, a meaningful statement is that the reduction or collapse of a wavefunction occurs after a recording has been made by an *irreversible* amplification of an atomic event by a macroscopic detector, like a Geiger counter or a photographic plate. The combination of eye lens, retina, optical nerve and neural memory cells can be regarded as a detector, for the special case of photons in a visible frequency range, but such a detector is unique to a single observer.

The most accurate way of describing the state of the unobserved atom is to put into English the mathematics describing the state of the atom before we looked to see where it is: The atom was *simultaneously in two states*: in the first state, it is *in-the-top-box-and-not-in-the-bottom-box*, and simultaneously in the second state it is *in-the-bottom-box-and-not-in-the-top-box* (p.79 t.15)

This so called "accurate" description is actually pure metaphysics, since it is not possible to establish the location of an "unobserved" atom. According to quantum theory, before an observation is made there is only a *probability* of finding the atom in either the top or the bottom box. The essence of quantum physics is that nothing definite can be said about the location of the atom before a measurement of it is made. For example, we can send a beam of photons into a box and detect the scattered photons. This can establish approximately the localization of the atom *at the time* of the interaction of the photon and the atom, but not at any time before this interaction took place

But randomness was not Einstein's most serious problem with quantum mechanics. What disturbed Einstein and Schrödinger, and more people today, is quantum mechanics' apparent denial of ordinary physical reality - or, maybe the same thing, the need to include the observer in the physical description - an intrusion of consciousness into the physical world (p.80 t.8)

While Einstein was concerned with the nature of physical reality, it is highly misleading to indicate that it is the "same thing" to imply that he was concerned with the "intrusion of consciousness into the physical world". On the contrary, he made it clear that the generally accepted statistical interpretation of the wavefunction is an " *objective* description whose concepts clearly make sense independently of the observation and the *observer* (see the next section for the full quotation in his letter to Born a year before his death)

John Bell felt that the quantum mechanical description will be superseded... It carries in itself the seeds of its own destruction'' ... He feels that '' the new way of seeing things will involve an imaginative leap that will astonish us'' (p.87 t.5)

The authors of QE fail to point out that this quotation appeared in an article written jointly by Bell and myself about 40 years ago [15]. But neither of them bothered to ask my current views on this subject. I would like to take the opportunity to make a disclaimer here. In our paper we also said, tongue in cheek, that

The experiment may be said to start with the printed proposal and to end with the issue of the report. The laboratory, the experimenter, the administration, and the editorial staff of the Physical Review are all just part of the instrumentation. The incorporation of (presumably) conscious experimenters and editors into the equipment raises a very intriguing question... If the interference is destroyed, then the Schrodinger equation is incorrect for systems containing consciousness. If the interference is not destroyed, the quantum mechanical description is revealed as not wrong but certainly incomplete.

In a footnote we added that “we emphasize not only that our view is that of a minority but also that current interest in such questions is small. The typical physicist feels that they have been long answered, and that he will fully understand just how if ever he can spare twenty minutes to think about it ”. (As a graduate student, one of the authors, Bruce Rosenblum, reports that he “ assumed that if I spent an hour or so thinking it through [the wave particle duality] I’d see it all clearly“ (ref. [2], p. 10).)

At the time that we made these comments, I did not understand that a Geiger counter, a photographic film, the retina of the eye and associated neural connections. or any other detector creates a more or less permanent record by means of physical and/or chemical processes that are *irreversible*. As in thermodynamics, such processes involve a very large number of atoms which are involved through an amplification process essential to the creation of a recording⁵.

A major failure of QE is that this essential feature of the measurement process in quantum theory is not even mentioned. It is worth remembering that irreversibility already was a conundrum for classical physics because the basic equations are time reversal invariant. The same invariance applies to the basic equations in quantum mechanics. The emergence of irreversibility occurs in systems with large number of particles, which is the case with recording devices, and constitutes the foundations of statistical thermodynamics [17].

There is no official Copenhagen interpretation. But every version grabs the bull by the horns and asserts that an *observation produces the property observed* (p.100 t.11)

Read, for example, the quotations of Bohr, Heisenberg, Einstein and others quoted here and in the next section to see that none of them ever made

⁵Following Bohr’s admonition to discuss the details of the measuring apparatus, we note that a typical photographic film consist of an irregular array of silver bromide ionic crystals suspended on an emulsion. The absorption of a photon ejects an electron which gives rise to a catalytic reaction where a very large number of silver ions transform into silver atoms. After the film is processed these silver atoms give rise to a spot which absorbs visible light shining on it, thus producing a dark spot which approximately marks the position on the screen where the photon had landed. The cascade of silver ions into silver atoms produced by the photon is the amplification which gives rise to an irreversible process, and therefore it is not described by the evolution of a simple wavefunction.

such a nonsense statement as “produces the property observed” when referring to an observation.

Even students completing a course in quantum mechanics, when asked what the wavefunction tells, often incorrectly respond that it gives the probability where the object is (p.103 t.7)

Actually, the student’s response is essentially correct if it is somewhat modified by stating that “it is the probability where the object is found by an experiment designed to establish the position of the object ”.

Our concern is with the consciousness central to the quantum enigma - the awareness that appears to affect physical phenomena. Our simple example was that your observation of an object wholly in a single box *caused* it to be there, because you presumably *could* have chosen to *cause* an interference pattern establishing a contradictory situation, whereby the object would have been a wave simultaneously in two boxes (p. 168) (p.168 t.18)

It is hard to imagine that more nonsense about the meaning of quantum theory could be encapsulated into a single sentence. To begin with, an experimental set up to observe in which of two boxes an atom is located does not “cause” such a localization. Instead, an observer who examines the output of a recording finds the location of the atom in accordance with a probability distribution given by the absolute square of the ψ function appropriate to the experimental arrangement. A different experimental set up may lead to observations of interference patterns by coherent atomic beams, but these patterns are not “caused” by the “awareness” of the observer. The interference patterns can be recorded on a photographic film and seen there by anyone examining this film. It is completely ridiculous to propose that someone who sees the interference pattern on the film “caused” it to be there. The claim that by “choosing” the experimental set up the observer “caused” a particular outcome is a bizarre use of the word “cause” which has nothing whatsoever to do with quantum theory. Bohr must be turning over on his grave.

According to the authors of QE, *consciousness* is suppose to enter into quantum theory because the observer can choose (“free will”) the experimental setup which demonstrates in this case complementary aspects, wave or particle behaviour, of a photon, electron or other atomic objects. But the choice of experiment can also be made, for example, by flipping a coin

Does such a demonstration necessarily require a *conscious* observer? Couldn't a conscious robot, or even a Geiger counter, do the observing? That most commonly voiced objection to consciusnes being required comes up - and is refuted-in our next chapter. For now, just recall that, according to quantum theory, if that robot or Geiger counter were not in contact with the rest of the world it would merely entangle to become part of a total superposition state -as did Schrödinger's cat. In that sense it would not truly *observe* (p.168 b.12)

The operation of a Geiger counter is well understood, and it satisfies the condition necessary to establish an observation, namely the irreversible amplification of an atomic signal to create a semi-permanent record of an atomic event. The only important contact of a Geiger counter to the “rest of the world” is a power cable, which has to be plugged into a wall socket from which electricity flows from a power plant. A battery would also be sufficient.

Classical physics, Newtonian physics, is completely deterministic. An ‘‘all seeing eye’’, knowing the situation of the universe at one time, can know its entire future. If classical physics applied to everything, there would be no place for free will (p.169 t.11)

This familiar quotation, due to Pierre Simon Laplace in the 18th century, was later own to be false by Henri Poincaré. Laplace was not aware that Newtonian mechanics could lead to chaotic motion, and that in practice classical theory also is not deterministic, because of “sensitivity to initial conditions”.⁶ The implication that quantum mechanics is somehow essential to *free will*,

⁶Doubters should play with the double pendulum in the entrance of our physics dept., which I had build by our mechanics shop to demonstrate chaotic dynamics.

which is supported by some philosophers of science, is not valid⁷

The Encounter “Officially” Proclaimed (p.180 t.1)

In his rigorous 1932 treatment ‘‘The Mathematical Foundations of Quantum Mechanics’’, John von Neumann showed that quantum theory makes physics encounter with consciousness *inevitable* [my italics] (p.180 t.1)

But in the next sentence, one finds that this “inevitable encounter” occurs because von Neumann has treated a Geiger counter by a trivial wavefunction consisting of the superposition of only two states: whether it is in a “fired” or in an “unfired” state. This model of a Geiger counter, however, is *incorrect*, because it does not describe the *essential* property of such a detector which is to be able to make a permanent *record* of an atomic event. Such a recording requires an *irreversible* process.

You’re prompted to investigate how the robot chose which experiment to do in each case. Suppose that you find that it flipped a coin. Heads it did the look-in-the-box experiment; tails the interference experiment. You find something puzzling about this: The coin’s landing seems inexplicably connected with what was presumably in a particular box-pair set. Unless ours is a strangely deterministic world, one that conspired to correlate the coin landing with what was in the box pairs, there is no physical mechanism for that correlation. (p.183 b.15)

The outlandish notion that there exists a correlation between the “coin landing” and the outcome of an experiment is tied to the previous bizarre claim that an observer can “cause” this outcome. This is the consequence of the sloppy language which Bohr had warned should be avoided.

⁷Some time ago I had an argument about this issue with the Berkeley philosopher John Searle who did not seem to be aware that the *noise* due to finite temperature thermal fluctuations in the firing of neural brain cells is more important than the zero temperature quantum fluctuations or effects of the uncertainty principle.

You therefore replace the robot's coin flipping by the one decision mechanism you are sure is not connected with what supposedly exists in a particular box-pair set: *your own free choice*. You push a button telling the robot which experiment to do with each box-pair set. You now find that by your conscious free choice of experiment you can prove either that the objects were concentrated or that they were distributed. You can choose to prove either of two contradictory things. You are faced with the quantum enigma, and consciousness is involved. (p.183 b.8)

If you have had the patience to come this far, you finally will have found out how, according to the authors of QE, *physics encounters consciousness*: by replacing the decision making of a robot who flips coins with the *free will of a conscious observer*. This claim, however, does not make any sense because as a "conscious observer" you can also make decisions based on flipping coins rather than on your free will. Following the logic of the authors of QE, you would have to conclude that *physics encounters coin flipping*. It should be pointed out that while a few eminent physicists such as Eugene Wigner believe that consciousness plays a role in the *collapse* of the wavefunction, he did not argue that this role has anything to do with "free will". This is a new and unsubstantiated twist to the role of consciousness given by the authors of QE. Such a bias should not be fostered on the general public as a generally accepted notion in modern physics ⁸

⁸It is easy to demonstrate that the persistent claim of the authors of QE that it is necessary to choose or flip a coin to decide which of their two *gedanken* experiment should be performed can be avoided by performing *both* experiments at the same time. Light of appropriate frequency and variable intensity is shined on the two slits through which individual atoms of fixed momentum are directed. Then a scattered photon can record through which slit an atom passed, and a photographic plate can record the position where the atom lands later on. All the spots that are recorded on the photographic plate are then separated into two classes of events: a) events where a scattered photon is detected and b) events where no scattered photon is recorded. According to quantum theory, events of class b) show the familiar interference pattern characteristic of the two slit experiment. Events of class a) do not show this interference pattern. The fraction of the events in class a) and b) depends on the intensity of the light shining on the two slits: the weaker the intensity the greater the number of events in class a) and viceversa. It is assumed here that the detector of scattered photons is very efficient, otherwise the interference pattern will be somewhat smeared out, because it contains also events where a scattered photon

If we consider the robot argument from the view point of quantum theory, the isolated robot is a quantum system, and von Neumann's conclusion applies: the robot entangles with the object in the box pairs: and the objects wavefunction does not collapse into a single box until a conscious observer views the robot's printout (p.184 t.1)

The notion that the the "robot entangles with the object", implying that the robot, or for that matter any macroscopic measuring apparatus like a Geiger counter or a photographic film, can be represented by a wavefunction ψ is *incorrect*. The essential property of macroscopic systems like robots is that these systems are able to create a record of an atomic event by a mechanism of amplification which is irreversible. This mechanism has nothing whatsoever to do with consciousness.

In conclusion, I like to quote John Wheeler [14]

Caution: "Consciousness" has nothing whatsoever to do with quantum process. We are dealing with an event that makes itself known by an irreversible act of amplification, by an indelible record, an act of registration. Does that record subsequently enter into the "consciousness" of some person, some animal or some computer? Is that the first step into translating the measurement into "meaning" - meaning regarded as "the joint product of all the evidence that is available to those who communicate". Then that is a separate part of the story, important but not to be confused with "quantum phenomena".

This quotation, but in a truncated form, appears in QE, p. 165. What is left out in their quotation is Wheeler's precise definition for the word *meaning*. The authors of QE comment to Wheeler's remark

We take this as an injunction to physicists (as physicists) to study only the quantum phenomena, not the *meaning* of the phenomena.

But Wheeler's *injunction* is only *against* claiming that consciousness has something to do with quantum phenomena, which is the central theme of QE. It

from an atom was not detected

is not an injunction against studying the cognitive processes in the brain associated with consciousness, which are “a separate part of the story, important but not to be confused with quantum phenomena”.

Remarks on the quantum measurement process by some of the founders of the quantum theory, and by prominent contemporary physicists

Below, I have included some quotations on quantum measurement and the role of the observer by the founders of quantum theory and some prominent contemporary physicists which are relevant to my critique of QE.

Bohr (1958)

Far from involving any special intricacy, the irreversible amplification effects which the recording of the presence of atomic objects rests rather reminds of the essential irreversibility inherent in the very concept of observation. The description of atomic phenomena has in these respects a perfectly objective [my italics] character, in the sense that no explicit reference is made to any individual observer and that therefore, with proper regard to relativistic exigences, no ambiguity is involved in the communication of information [8]

W. Heisenberg (1958)

The probability function does - unlike the common procedure in Newtonian mechanics - not describe a certain event but, at least during the process of observation, a whole ensemble [my italics] of events...When the old adage “Natura non facit saltus”⁹ is used as a basis of criticism of quantum theory, we can reply that certainly our knowledge can change suddenly and that this fact justifies the use of the term “quantum jumps” [or collapse of the wavefunction].

Therefore, the transition from the “possible” to the “actual” takes place during the act of observation. If we want to describe what

⁹Nature does not ...jumps.

*happens in an atomic event, we have to realize that the word "happens" can apply only to the observation, not to the state of affairs between two observations. It applies to the physical, not the *psychical* [my italics] act of observation, and we may say that the transition from the "possible" to the "actual" takes place as soon as the interaction of the object with the measuring device, and therefore with the rest of the world, has come into play; it is not connected with the act of registration of the result by the *mind* [my italics] of the observer. The discontinuous change in the probability function [collapse of the wavefunction], however, takes place with the act of registration, because it is the discontinuous change of our knowledge in the instant of registration that has its image in the discontinuous change of the probability function. ...Certainly quantum theory does not contain genuine subjective features, it does not introduce the *mind* [my italics] of the physicist as a part of the atomic event [9].*

Einstein (1949)

*One arrives at very implausible theoretical conceptions, if one attempts to maintain the thesis that the statistical quantum theory is in principle capable of producing a complete description of an *individual* [my italics] physical system. On the other hand, those difficulties of theoretical interpretation disappear, if one views the quantum mechanical description as the description of ensembles of systems.*

*I reached this conclusion as the result of quite different types of considerations. I am convinced that everyone who will take the trouble to carry through such reflections *conscientiously* [my italics] will find himself finally driven to this interpretation of quantum -theoretical description (the ψ function is to be understood as the description not of a single system but of an ensemble of systems) [10]*

Einstein (1953)

All the same it is not difficult to regard the step into probabilistic quantum theory as final. One only has to assume that the ψ

function relates to an ensemble [my italics], and not to an individual case... The interpretation of the ψ function as relating to an ensemble also eliminates the paradox that a measurement carried out in one part of space determines the kind of expectation for a measurement carried out later in another part of space (coupling of parts of systems far apart in space) [11]

Einstein (1954)

*The concept that the ψ -function completely describes the physical behaviour of the individual single system is untenable*¹⁰ But one

¹⁰Einstein reached this conclusion by the following argument:

My assertion is this: the ψ function cannot be regarded as a complete description of the system, only as an incomplete one. In other words: there are attributes of the individual system whose reality no on doubts but which the description by means of the ψ function does not include.

I have tried to demonstrate this with a system which contains one ‘macro-coordinate’ (coordinate of the centre of a sphere of 1 mm diameter). The ψ function selected was that of fixed energy. This choice is permissible, because our question by its very nature must be answered so that the answer can claim validity for every ψ -function. From the considerations of this simplest case, it follows that - apart from the existing macro-structure according to the quantum theory - at any arbitrarily chosen time, the centre of the sphere is just as likely to be in one position (possible in accordance with the problem) as in any other. This means that the description by ψ -function does not contain anything which corresponds with a (quasi-) localization of the sphere at the selected time. The same applies to all systems where macro-coordinates can be distinguished.

In order to be able to draw a conclusion from this as to the physical interpretation of the ψ function we can use a concept which can claim to be valid independently of the quantum theory and which is unlikely to be rejected by anyone: any system is at any time (quasi-) sharp in relation to its macro-coordinates. If this were not the case, an approximate description of the world in macro-coordinates would obviously be impossible (‘localization theorem’). I now make the following assertion: if the description by a ψ -function could be regarded as the complete description for the physical condition of an individual system, one should be able to deduce the ‘localization theorem’ from the ψ -function and indeed from any ψ -function belonging to a system which has macro-coordinates. It is obvious that this is not so for the specific example which has been under consideration [12]

Stated in another way, the Schrödinger equation has solutions for ψ , such as a plane wave

can well make the following claim: if one regards the ψ function as the description of an *ensemble* it furnishes statements which - as far as we can judge - correspond satisfactorily to those of classical mechanics and at the same time account for the quantum structure of reality. In this interpretation [Born's statistical interpretation of quantum mechanics] the paradox of the apparent coupling of spatially separated parts of systems also disappears. Furthermore, it has the advantage that the description thus interpreted is an *objective* description whose concepts clearly make sense independently of the observation and the *observer* [my italics] [12]

Wheeler (1986)

No elementary quantum phenomenon is a phenomenon until it's brought to a close by an irreversible act of amplification by a detection such as the click of a geiger counter or the blackening of a grain of photographic emulsion[13].

J. Bell (1986)

I think the experimental facts which are usually offered to show that we must bring the observer into quantum theory do not compel us to adopt that conclusion [6]

The problem of measurement and the observer is the problem where the measurement begins and ends, and where the observer begins and ends...there are problems like this all the way from the retina through the optic nerve to the brain and so on. I think, that - when you analyse this language that the physicists have fallen into, that physics is about the result of observations - you find that on analysis it evaporates, and nothing very clear is being said. [6]

(fixed energy), which do not correspond to the description of the motion of any individual macroscopic object like Einstein's sphere which has also sharply localized position. But this solution does describe an *ensemble* of identical spheres which have centers distributed uniformly along the direction of motion, all moving with the same velocity.

References

- [1] Quoted in A. Pais *Subtle is the Lord...* (Clarendon Press, New York 1982) p.455
- [2] B. Rosenblum and F. Kuttner, *Quantum Enigma, Physics Encounters Consciousness* (Oxford Univ. Press, 2006)
- [3] M. Nauenberg and V.F. Weisskopf, *Why does the Sun shine* American Journal of Physics 46, 23 (1978)
- [4] M. Nauenberg, *The evolution of radiation towards thermal equilibrium: A soluble model which illustrates the foundations of statistical mechanics* Am. J. Physics 72, 313 (2004)
- [5] J.S. Bell *Speakable and unspeakable in quantum mechanics* Introductory remarks at Naples-Amalfi meeting, May 7, 1984. Reprinted in J.S. Bell *Speakable and unspeakable in quantum mechanics* (Cambridge Univ. Press 1987)
- [6] P.C.W. Davies and J.R. Brown, *Ghost in the Atom* (Cambridge Univ. Press. 1986) Interview with J. Bell, pp. 47-48
- [7] A. Leggett, *Reflections on the quantum measurement paradox* in *Quantum Implications* edited by (Routledge, London 1991) p.94
- [8] N. Bohr *Quantum Physics and Philosophy, Causality and Complementarity* in “Essays 1958-1962 on Atomic Physics and Human Knowledge” (Vintage Books, 1966)
- [9] W. Heisenberg, *Physics and Philosophy, The revolution in modern science* (Prometheos Books, New York, 1999) p. 55
- [10] *Albert Einstein: Philosopher-Scientist* v.II, edited by P.S. Schilpp (Harper, New York 1949) p. 67
- [11] A. Einstein in a letter to Max Born on Dec. 3, 1953 Reprinted in the “Born-Einstein letters 1916-1955 Translated into English by Irene Born (Macmillan Press, China 2005) p. 204

- [12] A. Einstein, Unpublished commentary sent in a letter to Max Born on 12 January 1954. Reprinted in the “Born-Einstein letters 1916-1955 Translated into English by Irene Born (Macmillan Press, China 2005) pp. 210-211
- [13] P.C.W. Davies and J.R.Brown, *Ghost in the Atom* (Cambridge Univ. Press. 1986) Interview with Wheeler p.61
- [14] J. Wheeler, *Law without law* in “Quantum Theory and Measurement” edited by J.A. Wheeler and Zurek (Princeton Univ. Press, 1983) p. 196
- [15] J.S. Bell and M. Nauenberg *The moral aspects of quantum mechanics* in ”Preludes in Theoretical Physics” edited by A. De Shalit and Herman Feschbach, and Leon van Hove (North Holland, Amsterdam 1966) pp. 279-286. Reprinted in J.S. Bell *Speakable and unspeakable in quantum mechanics* (Cambridge Univ. Press 1987) p. 22
- [16] R.P. Feynman, *Theory of Fundamental Processes* Notes taken from Feynman’s 1956 lectures at Cornell University by Peter Carruthers and Michael Nauenberg (Benjamin, New York 1961) pp 1-2
- [17] M. Nauenberg, *The evolution of radiation towards thermal equilibrium: A soluble model that illustrates the foundation of statistical physics* American Journal of Physics **72** 313 (2004)