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Research Article

Quantum states of a conscious observer

Richard A Mould

Department of Physics and Astronomy (Ret.)
State University of New York at Stony Brook, Stony Brook, NY 11794-3800
Email: richard.mould@stonybrook.edu

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ABSTRACT

Since the 1920s, probability has been extensively and successfully attributed to the square modulus of a quantum mechanical wave function. However, this has led to questions as to the nature of reality in quantum mechanics. Ambiguity arises because the notion of probability is tied to *observations* of the system rather than to *variables* of the system. To remedy this, we give probability an objective meaning rather than its classical-subjective meaning, and we identify it with a system variable that can generate a wave collapse—independent of an outside observer. Specifically, the definition of probability is related to *changes in* square modulus rather than to square modulus; and in addition, it is directly and causally linked to wave collapse. Square modulus is given no physical importance in this treatment. The traditional Born definition of probability is of course useful, but it is regarded here as inimical to physical understanding. The proposed treatment allows conscious persons (or cats) to be included in a quantum mechanical system without paradox, and it has microscopic as well as macroscopic applicability. It resolves many of the puzzling characteristics of quantum mechanics that are implicit in the Born (Copenhagen) interpretation.

Keywords: Born interpretation; Conscious brain states; Objective probability; Quantum observer; Reality in quantum mechanics; Wave function collapse

INTRODUCTION

The reliance on observation as the test of reality is a positivist proclivity that is problematic [1, 2]. On this basis, the quantum mechanical wave function cannot represent a physical system unless it is also observed. The gist of this widely accepted Copenhagen interpretation of quantum mechanics requires an outside agent to give a wave function ontological significance [3]. This is consistent with almost all of the current interpretations of quantum mechanics that fall back on the *a posteriori* (observed frequency) definition of probability coming to us from the 19th Century. This notion of probability has many valid applications in classical physics.

On the other hand, I believe that probability has a different meaning in quantum mechanics [4]. The universe had a reality about it long before there were conscious observers. It was not in superposition for 13.8 billion years waiting for one of us to come along in order to call down realized eigenvalues. The universe must therefore have a reality apart from ourselves and our observations, and it is our task to come as close to that reality as possible. We therefore say that the wave function makes an objective statement about the system that is independent of observation; and it refers to an observer independent notion of probability. Probability is not a cover-up of unknown variables, and it does not rely on subjective definitions to give it meaning. Instead, probability in this paper is objective and related to *changes of square modulus* rather than square modulus, and it makes no reference to an observer. Quantum mechanics thereby associates probability with *a system variable that generates a collapse of the wave* without any help from the outside. This allows any physical system to be represented by a realistic wave function, whether or not it is observed by, or includes, a conscious human observer-or a cat.

AN OBSERVER SEES A CAPTURE

Begin with the simple case of a particle interacting with a detector that is witnessed by a conscious observer. Prior to interaction, the particle p approaches the detector D that is overseen by a conscious observer O. The wave function at this stage is

$$\Psi(\textit{prior to interaction}) = \psi_p \psi_{DO} \qquad (1)$$

where ψ_p is the wave function of the as yet non-interacting particle, and ψ_{DO} is the wave function of the ground state detector that is being observed by the observer.

There is said to be a fundamental distinction between microscopic systems and macroscopic systems, and between conscious systems and non-conscious systems. It is basic to the Copenhagen tradition that these things are so different that they cannot be quantum mechanically commingled. I do not subscribe to that position. I'm sure that nature makes no such distinctions. The line between micro and macro is a human distinction—not a natural one. The difference between a conscious object and an unconscious one is certainly natural, but it is not quantum mechanically important. We have been swayed by our self-importance to adopt a self-reflective description of nature—a positivist account that elevates the man-made distinctions to a philosophical status. The Copenhagen form of this philosophy asserts that a macroscopic (i.e., human size) measuring device is fundamentally different from a microscopic object that it measures. Opposed to this, I believe that all physical systems are subject to the same laws whether they are micro or macro, measured or measuring, conscious or not, and there is no convincing evidence otherwise. A human-centric (i.e., subjective) philosophy is no challenge to the universality of physics. I therefore submit that Eq. 1 is a correct representation of the described physical situation. In that equation, the microscopic particle and the macroscopic detector/observer combination have an equal status.

Let the interaction between the particle and the detector begin at time t_0. An interaction term in the Hamiltonian then produces a second component $\psi_{D'O'}$ representing the result of the interaction in which the particle is inside of the measuring apparatus D'. During the time t of the particle/detector interaction, the state function Ψ is therefore

$$\Psi(t \geq t_0) = \psi_p(t)\,\psi_{DO} + \underline{\psi_{D'O'}}(t)\,\psi_\gamma(t) \qquad (2)$$

where $\underline{\psi_{D'O'}}(t)$ is the activated detector as seen by the conscious observer and $\psi_\gamma(t)$ is the photon field that is emitted when the particle enters the ion chamber of the detector. The underline of the second component will be explained below. The magnitude of the first component in this equation decreases in time, while the magnitude of the second component increases in such a way as to preserve normalization.

The Born interpretation of this progression recalls the familiar cat paradox. The norm (square modulus) of the first component in Eq. 2 is said by Born to be the probability that the observer sees one thing (like an alive cat) and the norm of the second component is the probability that the observer sees something else (like a dead cat). The paradox lies in the simultaneous reality of these unlike components, if hidden variables are not allowed.

Before introducing another interpretation of quantum mechanics, we note three points of interest about Eq. 2 that are important. First, the equation is valid only in the indicated time *during* the interaction and *before* there has been a capture. Physically, this means that the *first* term in Eq. 2 represents the reality of the system during time $t \geq t_0$, whereas the *second* term is not yet real—it is *unrealized* during time t. That is why the second term is underlined. An underline in this paper will always mean that the underlined term does not represent reality during the indicated time.

The second point of interest is that the norm (square modulus) of the first term is *orthogonal to* the norm of the second term. In the second term, particle p moves through the ion chamber of the detector as time progresses from t_0 to $t \geq t_0$, and during that time the particle ionizes many atoms. This produces bursts of photons $\psi_\gamma(t)$ in all directions. These photons are additional particles in the second term that produce *a change in particle composition* from the first term; so the first and second terms in Eq. 2 are orthogonal to one another because of the difference in photon occupation number. We call the discontinuous orthogonal gap between the two terms in this equation a *quantum jump*.

The third point of interest is that the "capture" of the particle will correspond to the "collapse" of the wave function into another equation. We call the time t_s the time of a *stochastic hit*—the time of a capture-collapse. The collapsed equation following Eq. 2 will be

$$\Psi(t \geq t_s) = \psi_{D'O'}\,\psi_\gamma(t) \qquad (3)$$

where $\psi_{D'O'}$ is the "realized" detector (no underline) that captures the particle at time t_s, plus the observer who views that detector in its final state. The equation is renormalized to 1.0.

INTERPRETATION

The proposed interpretation of quantum mechanics begins by saying that the square modulus of a quantum mechanical component has *no* physical significance. The Born interpretation assigns probability to the square modulus, and in practice that is a very useful thing to do. One can make good use of the Born rule because of its broad applicability in physics; but in the proposed interpretation of physics, probability is given another assignment. Useful as it has been, the Born rule is one source of the positivistic, human-oriented (subjective) ideas that have confused our grasp of the mechanics. For a correct understanding of the objective nature of this science, we treat quantum probability differently. In place of the Born rule we propose the following rule.

RULE: *The square modular flow J going from the norm of a realized component into the norm of an unrealized component is equal to the probability per unit time that there will be a stochastic hit on the unrealized component, thereby collapsing the wave function. Only the unrealized component survives the collapse as a normalized realized component.*

This defines the variable

J = the probability of collapse per unit of time

and assigns it to increases in the square modulus of the second component in Eq. 2. So in a given interval of time dt, the value of Jdt equals the probability that the second term will be stochastically chosen in that time. If that happens, the system will collapse to Eq. 3. The variable J will also be called "probability flow".

The observer is not a factor in either the above meaning of probability or in the collapse of the wave. Probability applies objectively to the system. It can be macroscopic or it can be microscopic, or any combination; and it can be conscious or unconscious, or any combination. There is no cat paradox because there is just one real component (without an underlie) in Eq. 2. So if the cat is alive in that component, then it is alive; and if it is dead in that component, then it is dead. There is no ambiguity on this point.

NEUTRON DEAY

To demonstrate the generalizability of these ideas it is useful to look at some other processes, and neutron decay is a good example. A free neutron is represented by the state equation

$$\Upsilon(t > t_0) = n(t) + \underline{e}p\bar{n}(t) \tag{4}$$

where n is a neutron, e is an electron, p is a proton, and $\bar{n}$ is an antineutrino. Instead of writing ψ_n, ψ_e, and etc., we drop the reference to ψ and write simply n, e, and etc. for each particle in a state function given by Ψ. The underline of $\underline{e}$ means that the second component is as yet unrealized, whereas the first component is realized during the indicated time $t \geq t_0$. It does not matter which state is underlined in an unrealized component. As before, this equation represents a "quantum jump" in which there is a discontinuous change in particle composition. In this case there is a change in the occupation number of each particle in the system—guaranteeing that the two components are orthogonal.

There is a probability flow J from the first to the second component in Eq. 4 that represents the probability per unit time that there will be a stochastic hit on the second component and a consequent collapse of the state. If that occurs at a time t_s the collapsed system will be

$$\Upsilon(t \geq t_s > t_0) = ep\bar{n}(t) \tag{5}$$

where the decay products are now empirically realized.

Here again the collapse of the wave is objectively defined in terms of its probability, and without reference to an outside observer or recording device.

All decays are represented here as being instantaneous, which means that the collapse begins at the moment of a stochastic hit. We ignore subsequent disruptive changes in the state function when writing these equations, and go directly from the pre-collapse state $n(t) + \underline{e}p\bar{v}(t)$ to the post-collapse state $ep\bar{n}(t)$.

ORTHOGONALITY

Orthogonality is important in each of the above cases because the RULE in the third section would otherwise be ambiguous. Let the state function of a system be given by

$$\Psi(t) = \psi_1(t) + \underline{\psi_2}(t) \tag{6}$$

Taking the square modulus of both sides and integrating over all the system variables except time gives

$$\int \Psi^*\Psi(t) = \int \psi_1{}^*\psi_1(t) + \int \underline{\psi_2}{}^*\underline{\psi_2}(t) \tag{7}$$

Because the components in this equation are orthogonal to each other there is no cross term. The RULE speaks of the "square modular flow going from a realized component into an unrealized component …"; so if there were a cross term in Eq. 7, these instructions would be ambiguous.

SERIAL REDUCTIONS

In another example, consider a counter C that is activated by an incoming field of particles. C_0 is the counter before it captures a single particle, C_1 is the counter after it captures one particle, and C_2 is the counter after it has captures two particles, etc. The state equation is

$$\Psi(t > t_0) = C_0(t) + \underline{C_1}\gamma_1(t) + \underline{C_2}\gamma_1\gamma_2(t) + \ldots \tag{8}$$

where the change in particle composition from one term to the next is given by the photons $\gamma(t)$ created in the ion chamber of each term—as in Eq. 2. The field of incoming particles is not represented in this equation because it adds nothing to the analysis. For notational convenience, we drop the time reference on the right side of Eq. 8.

After time t_0, probability flow J goes from C_0, to $\underline{C_1}$, and another J goes from $\underline{C_1}$ to $\underline{C_2}$, etc. However, this flow can only make a stochastic hit on the unrealized state $\underline{C_1}$ (causing it to become realized) because the other unrealized components in Eq. 8 cannot physically materialize before $\underline{C_1}$. The counter cannot be in a state C_2 before it is in a state C_1. Accordingly, the RULE in the third section requires that the probability flow J entering an unrealized component must come from a realized component in order to cause a stochastic hit and state reduction. So the probability flow from $\underline{C_1}$ to $\underline{C_2}$ will come to nothing, and the probability flow from C_0 to $\underline{C_1}$ will run its course without interruption until there is a stochastic hit on C_1 at some time t_{s1}. This causes a collapse to

$$\Psi(t = t_{s1} > t_0) = C_1\gamma_1 \tag{9}$$

At this point the probability flow from $C_1\gamma_1$ will give rise to a component $C_2\gamma_1\gamma_2$ and then $C_3\gamma_1\gamma_2\gamma_3$; so in time the equation becomes

$$\Psi(t > t_{sc1} > t_0) = C_1\gamma_1 + \underline{C_2}\gamma_1\gamma_2 + \underline{C_3}\gamma_1\gamma_2\gamma_3 + \ldots \tag{10}$$

Probability flow from $\underline{C_2}\gamma_1\gamma_2$ to $\underline{C_3}\,\gamma_1\gamma_2\gamma_3$ has no affect on the probability of a hit on $\underline{C_3}\gamma_1\gamma_2\gamma_3$ because according to the RULE, a hit depends only on flow coming into $\underline{C_2}\gamma_1\gamma_2$ from the realized component $C_1\gamma_1$. The equation therefore leads to a stochastic hit on $\underline{C_2}\gamma_1\gamma_2$ at time t_{s2} giving

$$\Psi(t = t_{s2} > t_{s1} > t_0) = C_2\gamma_1\gamma_2 \tag{11}$$

followed by

$$S(t > t_{s2} > t_{sc1} > t_0) = C_2\gamma_1\gamma_2 + \underline{C}_3\gamma_1\gamma_2\gamma_3 + \underline{C}_4\gamma_1\gamma_2\gamma_3\gamma_4 + \ldots \quad (12)$$

and so forth.

This description of serial reductions can be applied to microscopic states as well. Quantum mechanics so considered makes no distinction between microscopic states and macroscopic states. An atom that decays from an initial excited state a_0 will go to the next lower energy state a_1 and then to the next lower energy state a_2 without skipping a step, unless the Hamiltonian allows a skip to occur. If a skip is not allowed, then the system will follow the example of Eq. 8 starting with

$$\Psi(t > t_0) = a_0 + \underline{a}_1\gamma_1 + \underline{a}_2\gamma_1\gamma_2 \quad (13)$$

analogous with Eq. 8, where the added particles in the unrealized terms are the photons that are emitted with each drop in energy level.

The probability flow into $\underline{a}_1$ will eventually lead to a state reduction at time t_{s1} giving

$$\Psi(t = t_{s1} > t_0) = a_1\gamma_1 \quad (14)$$

after which

$$\Psi(t > t_{s1} > t_0) = a_1\gamma_1 + \underline{a}_2\gamma_1\gamma_2 \quad (15)$$

leading to a final collapse at t_{s2}.

$$\Psi(t = t_{s2} > t_{s1} > t_0) = a_2\,\gamma_1\gamma_2 \quad (16)$$

PARALLEL PATHS

Parallel paths demonstrate how the present treatment deals with more than one eigenvalue. Imagine two side-by-side counters C_1 and C_2 that are exposed to a radioactive source. Both counters turn off after a single capture. During the interaction the state equation is

$$\Psi(t > t_0) = C_1C_2 + \underline{C}'_1C_2 + \underline{C}_1C'_2 \quad (17)$$

where C_1C_2 is the initial state in which neither counter has captured a particle. Probability flows equally from the realized component to each one of the unrealized components, where C'_1 means that the first counter has captured a particle and C'_2 means that the second counter has captured a particle. The change in particle composition from one component to the next is due to the release of photons (not shown) inside the counters C'1 and C'2. Probability flow J_1 into the first component and the flow J_2 into the second component combine $(J_1 + J_2)dt$ to give the total probability of a stochastic hit on the counter system during the time dt. The radioactive source and its decay particles as well as the detector's scattered photons are not included in the equation because they add nothing to the argument, apart from the scattered photons in each component being responsible for the change of particle composition.

With probability flow into each of the un-realized components, both are equal candidates for a stochastic hit. If the first component is chosen at a time t_{s1} then

$$\Psi(t = t_{s1} > t_0) = C'_1C_2 \quad (18)$$

A further evolution of the wave function gives

$$\Psi(t > t_{s1} > t_0) = C'_1C_2 + \underline{C}'_1C'_2 \quad (19)$$

where $C'_1C'_2$ is the final component that is accessible through either C'_1C_2 or $C_1C'_2$. This equation is followed by a collapse to

$$\Psi(t \geq t_{s2} > t_{s1} > t_0) = C'_1C'_2 \quad (20)$$

This description of parallel reductions can be applied to microscopic states as well. An atom that decays from an initial excited state a_0 can go to either a_1 or a_2 with probability flows J_1 and J_2. As in the above series case, the initial equation is

$$\Psi(t > t_0) = a_0 + \underline{a}_1 + \underline{a}_2 \quad (21)$$

where again, J_1 and J_2 flow simultaneously into both unrealized components, placing them in competition with one another. In this case the change in particle composition from one component to the next is due to the release of a photon (not shown) as the atom falls to a lower energy level.

ATOMIC ABSORBTION AND EMISSION

Let an atom a in its ground state interact with a laser field γ_N containing N photons. These have an energy equal to the difference between the ground state a_0 and the first excited state a_1. The interaction with the laser field will then produce a stimulated absorption and emission that is given by

$$\Psi(t \geq t_0) = \gamma_N a_0(t) \Leftrightarrow \gamma_{N-1}a_1(t) \quad (22)$$

The first component is the laser field with N photons coexisting with the atom in its ground state, and the second component is the laser field with one less photon coexisting with the atom in its first excited state. These two realized components oscillate back and forth. The probability flow in this case produces no stochastic hit or state reduction. Just as the RULE implies that the flow between unrealized components does not cause a stochastic reduction, it also implies that a flow between realized components will not cause a stochastic reduction. *A stochastic hit can only occur with a probability flow from a realized to an unrealized component*—only when it is a quantum jump. The above oscillation might look like quantum jumping, but it does not satisfy the RULE because there are no unrealized states involved. The two components are orthogonal to one another because they constitute a change in the photon composition.

In addition to this stimulated oscillation, there will be a spontaneous emission of a photon from the first excited state. This gives the following state equation that begins when the atom and the laser field first interact with each other at t_0.

$$\Psi(t > t_0) = \gamma_N a_0 \Leftrightarrow \gamma_{N-1}a_1 + \gamma_{N-1}\underline{a}_0 \times \gamma \quad (23)$$

The quantum jump in this case goes from the second realized component to the unrealized third component, where the later is orthogonal to the former because of a change in the energy level of the atom. The multiplication sign in the last component is intended to distinguish the emitted photon from those in the laser beam.

This equation says that the system will initially oscillate between the two real components; and to the extent that the atom is in its excited state a_1 during this oscillation, it will feed probability flow to the last component. If that flow causes a stochastic hit at time t_{s1} the system will reduce to the realized component giving

$$\Psi(t = t_{s1} > t_0) = \gamma_{N-1} a_0 \times \gamma \tag{24}$$

The process is then repeated leading to a second stochastic hit at time t_{s2} that gives

$$\Psi(t = t_{s2} > t_{s1} > t_0) = \gamma_{N-2} a_0 \times 2\gamma \tag{25}$$

after which the process is again repeated.

OBJECTIVE PROBABILITY

The classical idea of probability is a measure of our ignorance. When we flip a coin in the air we do not have a sufficient knowledge of the forces involved to predict the outcome—heads or tails, so we assign a probability. Classical probability is then a *measure of our ignorance*. I believe that quantum mechanical probability is different. It is not a probability of ignorance. It has objective meaning of a kind that tells us when to expect something to happen. I do not believe that nature schedules collapse events on the basis of our ignorance of the system; and surely nature arranges particle captures and decays without taking our observations into account. The universe therefore has its own meaning of probability that is independent of humans. All we can do is adequately represent that probability in our theories, and I believe this is achieved in quantum mechanics when we define probability as above.

CONCLUSION

There are five ideas that are fundamental to this treatment of quantum mechanics.

First: Microscopic systems and macroscopic systems (including possible conscious observers and measuring devices) have equal status in quantum mechanical equations, independent of external conscious observers.

Second: When an interaction causes one or more new components to appear in a quantum mechanical equation, a new component will refer to a state of the system that does not yet exist. The initial component is called "realized", indicating that it is empirically real during this time, and a newly produced component is called "unrealized" indicating that it is not yet empirically real. There is only one realized component in one equation, but there may be many unrealized components.

Third: A discontinuity only appears in the evolution of the state function when the particle composition changes. Otherwise the evolution is continuous.

Fourth: When the probability per unit time J flows from a realized component to an unrealized component, Jdt is the probability that the unrealized component will be stochastically chosen in time dt. Quantum probability has an objective meaning. The quantity J between two components is equal to the change in the norm (square modulus) from one to the next.

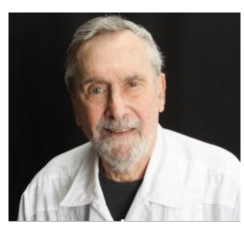
Fifth: When an unrealized component is stochastically chosen it will become realized and normalized, and *all other* components will collapse to zero.

Following these rules, quantum mechanics becomes an objective science. It is free of ontological paradox, and it replaces the Born interpretation that is the source of confusion in the Copenhagen view of quantum mechanics

REFERENCES

1. Bohr N., Atomic Physics and Human Knowledge. Wiley, New York, 1958, 60
2. Heisenberg W., A Representation of Nature in Contemporary Physics. Daedalus 1958, 87, 95-108
3. Stapp H., Mind, Matter, and Quantum Mechanics. Springer, New York, 1993, 49
4. Margenau H., The Nature of Physical Reality. McGraw-Hill, New York, 1950, 252-25

About Author



In 1951 Dr. Richard A Mould received a BS in Engineering Physics from Lehigh University, Bethlehem PA (USA); and he received a PhD in Physics in 1957 from Yale University, New Haven CT (USA). He then joined the faculty of the New York State University at Stony Brook. He spent 40 years in the Department of Physics and Astronomy at Stony Brook, retiring in 1997.