

# Objective vs Observer Measurements

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*Post-inflationary boundary conditions are essential to the existence of our highly structured universe, and these can only come about through quantum mechanical state reductions – i.e., through measurements. The choice is between: An ‘objective’ measurement that allows reduction to occur independent of conscious observers, and an ‘observer’ based measurement that ties reduction to the existence of a conscious observer. It is shown in this paper that that choice cannot be determined empirically; so how we finally understand state reduction will be decided by the way that reduction is used in a wider (future) theoretical framework.*

## Introduction

In four previous papers [1, 2, 3, 4], five rules of engagement are given that describe how conscious observers engage quantum mechanical systems. These rules do not include the Born rule (i.e., the Born interpretation) that is replaced in this treatment by a rule that introduces probability through *probability current* only. A summary of these rules and a more general discussion about them appears in another paper [5].

The 1<sup>st</sup> rule describes a stochastic trigger that selects an eigenvalue of some variable on the basis of probability current. The 2<sup>nd</sup> rule is a selection rule that provides for the creation of ‘ready’ brain states. These are brain states that are not initially conscious, but will become conscious the moment they are stochastically chosen. The 3<sup>rd</sup> rule says that when a ready brain state is stochastically chosen it will become conscious, and that all the other components will go to zero. The 4<sup>th</sup> rule is another selection rule

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that forbids a transition from a ready brain state to another ready brain state of the same observer. There is also a 5<sup>th</sup> rule that has no bearing on the problem discussed in this paper.

These rules provide for the collapse of a wave function in the presence of an observer. This collapse is specifically brought about by rule (3).

**Rule (3):** *If a component that is entangled with a ready brain state B is stochastically chosen, then B will become conscious, and all other components will be immediately reduced to zero.*

Such luminaries as Von Neumann, Wigner, London, and Bauer have championed the idea that stochastic choice in quantum mechanics depends on the presence of a conscious or potentially conscious observer as expressed by rule (3). However, there is wide opinion among physicists that measurement (i.e., a stochastic choice) should take place independent of the presence of a conscious observer. It is easy to write a rule that would provide for such an ‘objective’ reduction. I call it rule (1a).

**Rule (1a):** *If a component of a superposition is locally incoherent with other components in the superposition, and if it is stochastically chosen, then all those other components will be immediately reduced to zero.*

If the *environmental decoherence* affecting any subsystem is sufficient to make one of its components locally incoherent with other components, then according to rule (1a), a stochastic choice of that component will reduce all those other components to zero. A ‘state reduction’ of this kind will be called an *objective measurement* because an observer need not be present for it to occur.

This rule is not itself a theory. None of the rules referred to above constitute a theory. They are only *ad hoc* claims about nature that potentially reflect the requirements of a wider, but still unknown, theoretical framework. Rule (1a) for instance, might be validated by a spontaneous reduction theory like that of Ghirardi, Rimini, and Weber [6], or a gravitational theory like that of Penrose [7]. However, when considering rule (1a), I do not assume that one of these theories is correct; and in fact, I am not inclined to believe either one of them. That does not prevent me from assuming that rule (1a) is correct on the basis of some as yet unknown theory, nor does it prevent me from assuming that the other rules of engagement are correct in the same way. In this paper, as in the previous papers, I work only at the level of the rules themselves, without worrying about how they might be theoretically explained or justified. My goal is to get the right results (judged empirically) without regard to a rationale that might explain them. I do this by ‘grounding’ the solutions of Schrödinger’s equation as completely as possible in observation.

### **Rules (1-4) are still Necessary**

Even if rule (1a) is adopted, we will still need rules (1-4). Rule (1) will be required in any case in order to provide for the existence of a stochastic trigger; and when there is an observer in the picture, rule (2) will be required to insure the existence of ready brain states that perform the role described for them in refs. 1-5. Rule (3) should be modified in this case, for although it is necessary to insure that ready brain states become conscious when stochastically chosen, it would be redundant for rule (3) to also require a collapse of the wave function. So the adoption of rule (1a) should be coupled with a modification of rule (3) called rule (3mod), where the latter provides only for the conversion of a ready brain state to a conscious brain state upon stochastic choice. Rule (4) will also be necessary in an objective measurement scenario in order to prevent the appearance of the anomalous results described in refs. 1, 2, and 5.

An example of the effect of rule (1a) would be the reduction of the particle/detector system in eq. 1 in refs. 1 or 5. Prior to a stochastic hit at time  $t_{sc}$  we would have

$$\Phi(t_{sc} > t \geq t_0) = \psi(t)D_0 + D_1(t) \quad (1)$$

where the second component is zero at  $t_0$  and increases in time. The Schrödinger process provides the required probability current flow from the first component to the second component; and the two components will be incoherent almost as soon as the second one is formed. This insures an eventual stochastic hit on the second component according to rule (1), because that rule associates positive current flow with the probability per unit time of a stochastic hit. Since there is no observer in this picture, rules (1) and (1a) will be entirely sufficient to affect a state reduction in this *objective measurement*, yielding

$$\Phi(t \geq t_{sc} > t_0) = D_1$$

Any non-identity reduction is a *boundary reduction* because it creates a new boundary for Schrödinger's equation. See ref. 5 for a discussion of the importance of new boundaries in a post-inflationary universe.

Let an observer subsequently interact with  $D_1$ . Following a stochastic hit at time  $t_{sc(ob)}$  that occurs during the ensuing physiological interaction, rules (1), (1a), (2), and mod (3) will give rise to

$$\Phi(t \geq t_{sc(ob)} > t_{sc} > t_0) = D_1 \underline{B}_1 \quad (2)$$

where the underline means that the brain state  $\underline{B}_1$  is conscious.

Now consider what will happen if rule (1a) is *not in play* and rule (3) as originally stated is the sole source of state reduction. Then the detector in eq. 1 cannot by itself undergo state reduction, for an observer is not present. However, if a conscious observer is initially entangled with the detector, then the interaction will take the form given by eq. 2 in refs. 1 and 5.

$$\Phi(t \geq t_0) = \psi(t)D_0 \underline{B}_0 + D_1(t)B_1 \quad (3)$$

where the second component is zero at  $t_0$  and increases in time. The underlined brain state  $\underline{B}_0$  is conscious, and the not-underlined brain state  $B_1$  is a ready brain state. Rule (2) is necessary at this point to insure that the second component contains a ready brain state and not a conscious state. Rule (2) is a selection rule that prevents the brain's Hamiltonian from directly creating a discrete conscious state in this interaction.

Here again the current flow into the second component will cause a stochastic hit at some time  $t_{sc}$ . However, in this case the resulting state reduction will be due to rule (3) as originally stated, for rule (1a) is not in play. This is also a boundary reduction that is brought about by an *observer measurement* yielding

$$\Phi(t \geq t_{sc} > t_0) = D_1 \underline{B}_1 \quad (4)$$

which is empirically indistinguishable from the objective measurement leading to eq. 2.

Therefore, *the observer cannot know if rule (1a) or rule (3) is correct*. On purely empirical grounds we should therefore abandon rule (1a) citing Occam's razor. That's because we *must* provide for a state reduction in the presence of an observer, but it isn't empirically necessary to provide for a reduction otherwise. However, this matter will not be decided on empirical grounds. In the end, the choice will be made on the basis of the theoretical arguments that can be assembled on behalf of either kind of reduction.

## A Terminal Observer

A *terminal observer* is one who looks at the detector at a time  $t_{ob}$  after the time  $t_f$  when the particle/detector interaction has run its course. This gives rise to a physiological interaction that alters eq. 1 as shown in eq. 5 of ref. 1, giving

$$\begin{aligned} \Phi(t \geq t_{ob} > t_f) = & \psi(t) D_0 X + D_1(t_f) X \\ & + \psi'(t) D_0 B_0 + D_1'(t_f) B_1 \end{aligned} \quad (5)$$

where  $X$  is the unknown brain state of the observer who does not initially interact with the detector. Current flows from the first row to the second row in eq. 5, where the components in the second row are equal to zero prior to  $t_{ob}$ . Since ready brain states are

included in the only components that receive probability current, the stochastic choice that is made in this case will be the same for an observer measurement as for an objective measurement. So again, the observer cannot tell if rule (1a) is or is not in effect. The choice is empirically indeterminate.

### **Alternatives Empirically Unverifiable**

The above examples set the pattern. In the appendix of this paper I go through all of the remaining cases studied in refs. 1-2, and in all these cases the result is the same. The observer cannot tell if rule (1a) is or is not the correct reduction rule. I conclude that *it is impossible to empirically discriminate between an observer measurement scenario and an objective measurement scenario*. To quote a footnote in ref. 5,

“If an earlier boundary condition is uniquely correlated with a later observation, and if the observation is stochastically chosen by the rules (1-3) proposed above, then it will be impossible for the observer to know if the earlier boundary was also chosen by an earlier application of rule (1a). This will be true even if the boundary is not uniquely correlated with the observation. Causal correlations that connect back to a range of possible earlier ‘incoherent’ boundaries will result in uncertainty in the boundary conditions that led to the observation. So the precise nature of the earlier boundary cannot be verified by the observer, and there will be no reason for him to believe that any one of those possible boundaries was (or was not) the *only* boundary by virtue of an earlier rule (1a) reduction. Therefore, to this extent, the effects of rule (1a) are empirically indistinguishable from the effects of rule (3). An exception may seem to be possible if causal connections go back to a range of earlier ‘coherent’ boundaries; however, an example like this is worked out . . . with results that also support indistinguishability.” This example is in the next section.

## Nondemolition of Coherent Boundaries

The discussion so far has assumed that the initial system is either a single state or an incoherent superposition or mixture of states. But the question is: What will happen if the system is initially a ‘coherent’ superposition? If the result of a rule (3) observation depends on the properties of the superposition, then a rule (1a) reduction that occurs prior to that observation might produce different results. In that case, the observer would be able to tell if rule (1a) is or is not in effect. An example is the nondemolition measurement of a pair of  $1/2$  spin particles in a zero spin state. It should be possible to measure the total spin of this pair along any axis without measuring or interfering with their total spin along another axis, thus preserving the superposition. However, a rule (1a) reduction might occur when one of the two participating detectors makes contact with one of the particles, and that would destroy the superposition. It is shown below that that does not happen.

Let  $\Phi_1$  be the zero spin state ( $J^2 = 0$ ) =  $(2)^{-1/2}(\uparrow\downarrow - \downarrow\uparrow)$ , plus a pair of detectors. The detectors are represented by a single symbol  $D$  with two subscripts – the first for the variable that interacts with the first particle, and the second for the variable that interacts with the second particle. Either variable prior to the particle interaction is given by a subscript 0.

$$\Phi_1(\text{initially}) = (2)^{-1/2}(\uparrow\downarrow - \downarrow\uparrow)D_{00} \quad (6)$$

The two detectors are brought together at event **O** in fig. 1 so that their internal variables can be jointly prepared in a (prescribed) way that leaves them entangled throughout the experiment. The reason for this preparation will be explained below. The detectors separate after event **O**, allowing the first detector to interact with the first particle at event **A** (in fig. 1). This interaction occurs for a brief time between  $t_1$  and  $t_1 + \epsilon$ , giving

$$\begin{aligned} \Phi(t_1 + \varepsilon > t > t_1) = & c_1(t) \{(\uparrow\downarrow)D_{00} - (\downarrow\uparrow)D_{00}\} \\ & + c_2(t) \{(\uparrow D_{10})\downarrow - (\downarrow D_{10})\uparrow\} \end{aligned} \quad (7)$$

where the second row in eq. 7 is zero at time  $t_1$  and increases until time  $t_1 + \varepsilon$  when the first row goes to zero. The subscript 1 in  $D_{10}$  means that the first detector has interacted with the first particle. When this interaction is complete, the state is

$$\Phi_{II}(t_2 > t > t_1 + \varepsilon) = (2)^{-1/2} \{(\uparrow D_{10})\downarrow - (\downarrow D_{10})\uparrow\} \quad (8)$$

I do not indicate a difference between the subscript 1 that appears in the first component of eq. 8 and the subscript 1 that appears in the second component. It is true that these subscripts represent interactions with different spin directions of the first particle; but the detector's internal variable is chosen in such a way that the interaction causes it to become every bit as indefinite as the spin that it engages. As a result, each  $D_{10}$  in eq. 8 is indefinite, so there is no possibility of distinguishing between the two states apart from the spin vector to which each is correlated. Therefore, the first detector cannot separately “measure” spin up or spin down of the first particle in this interaction; and since both detector states are indefinite, the entire function  $\Phi_{II}$  is indefinite [8].

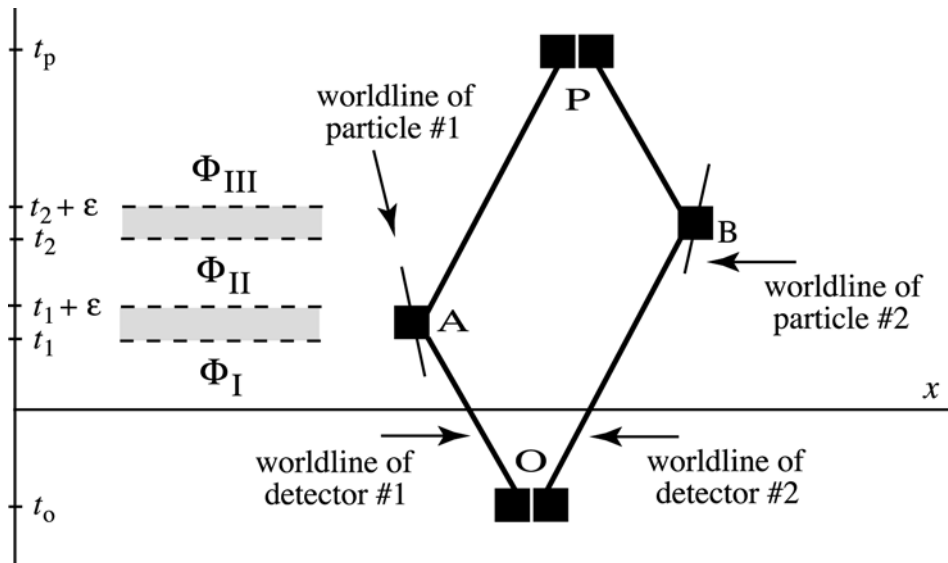


Figure 1

Following event **A**, the second detector interacts with the second particle at event **B** between times  $t_2$  and  $t_2 + \epsilon$ , giving

$$\begin{aligned} \Phi(t_2 + \epsilon > t > t_2) = & c_3(t) \{(\uparrow D_{10})\downarrow - (\downarrow D_{10})\uparrow\} \\ & + c_4(t) \{\uparrow D_{11}\downarrow - \downarrow D_{11}\uparrow\} \end{aligned} \quad (9)$$

where the second row is zero at time  $t_2$  and increases until time  $t_2 + \epsilon$  when the first row goes to zero. The final state of the system is therefore

$$\Phi_{\text{III}} = (2)^{-1/2} \{\uparrow D_{11}\downarrow - \downarrow D_{11}\uparrow\}$$

which is the same as ( $\mathcal{J}^2 = 0$ ) correlated with the final state of the detector pair.

$$\Phi_{\text{III}} = (2)^{-1/2} (\uparrow\downarrow - \downarrow\uparrow) D_{11} \quad (10)$$

Although the detector state in eq. 8 is indefinite, the interaction at event **B** restores the detectors to a definite state  $D_{11}$ . This restoration is possible because of the initial joint preparation of the detector variables at the time of event **O**. That preparation correlates the internal variables in such a way that the indefinite variable associated with the first detector (after event **A**) will add to the indefinite variable associated with the second detector (after event **B**), to yield a definite variable associated with  $D_{11}$ . See ref. 8. In this sequence, the detector pair has therefore made a definite nondemolition measurement of the particle pair, finding them in the coherent superposition  $(2)^{-1/2}(\uparrow\downarrow - \downarrow\uparrow)$  in which they began. Figure 1 shows the two detectors being physically reunited at event **P** so that their variables can be joined to give a definite result.

Now consider how state reduction might affect these results.

Let rule (3) be in play – and *not* rule (1a). The observer will look at the detectors at the beginning (event **O**) in order to verify the joint preparation of the internal variables of  $D_{00}$ . He will again look at the detectors at the end (event **P**) in order to confirm the results of the measurement. If the observer looks at detector at event **A** (or **B**) alone, the result will be indefinite. A state reduction at one of these events would therefore destroy the superposition. Definite results are observable only at the beginning and the end of the

experiment, and these preserve the superposition. Therefore, an observation and state reduction will be allowed at events **O** and **P**, but nowhere else.

On the other hand, imagine what will happen if rule (1a) is in play, *rather than* the reduction feature of rule (3). A state reduction will certainly occur at events **O** and **P**, because a stochastic hit during the detector/detector interaction will satisfy the requirements of rule (1a), as will a hit during the physiological interaction with the observer. The question is: Will rule (1a) also stochastically choose event **A** or **B**, thereby reducing the other component to zero, and thereby demolishing the zero spin state?

Consider event **A**. Rule (1a) reductions depend on a component of the superposition being locally incoherent with other components in the superposition. So the question is: Are the  $D_{10}$  detector states appearing in each component in eq. 8 locally incoherent; that is, are the environments associated with each of these detector states orthogonal?

The internal variables of the detectors appearing in the two components are correlated with one another, but they are separately indefinite. Their environments must not be allowed to interact with their respective internal variables, for that would destroy this correlation. As a result, the environment associated with one of the  $D_{10}$  states in eq. 8 is not measurably different than the environment associated with the other. Consequently these environments are not orthogonal, so the detector states in eq. 8 are not locally incoherent. Therefore, the conditions for a rule (1a) reduction are not met. The same might be said of the detectors emerging from event **B**.

It follows that even when rule (1a) has exclusive jurisdiction over reductions, a reduction will not occur at events **A** or **B**. However, there will be a reduction at events **O** and **P** because there will be a rule (1a) stochastic hit during the detector/detector interaction in each case, if not during a subsequent physiological interaction with the observer. Here again, the observer cannot know if his final observation results from these reductions due to rule (1a) or to rule (3). The superposition is preserved in either case.

In the previous section it was concluded that the distinction between an observer measurement scenario and an objective measurement scenario is experimentally unverifiable. This now appears to be true in the present example of initial coherence, as well as in all the other cases considered in this paper and in the Appendix.

### **Nature of the Choice**

We have a choice between the objective and the observer measurement scenarios. This is not just a matter of temperament, for it is also a matter of judgment as to what the future holds. There have been long suffering attempts to construct a theory that supports the idea of objective state reduction. None have been successful, and we have no reason to believe that there is such a theory. Nonetheless, many remain convinced that measurement must mean something independent of a conscious observer.

On the other hand, there is every reason to believe that there exists a theory of conscious brain states, for conscious brains are clearly a functioning part of Nature. There have been long suffering attempts in this direction too, but the effort to understand consciousness and conscious brains is just beginning.

It is my judgment that there is no general reduction theory independent of an observer<sup>2</sup>. I believe that a proper theory of consciousness will one day be found, and that it will provide the context in which the observer measurement scenario will be vindicated. A theory of that kind is surely necessary to validate the brain's selection rules (rules 2 and 4), and to address the part of rule (3) that changes a ready brain into a conscious brain. So either a future trans-Cartesian theory will naturally include state reduction through rule (3), *or* a separate theory will be found whose task is to validate rule (1a). I believe that the former is more likely.

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<sup>2</sup> A footnote in ref. 5 makes an exception to this conclusion. I don't think that superpositions of black holes are possible because of the singularity at the center. Therefore, it is entirely possible that the formation of a black hole automatically imposes a boundary condition on the universe that is equivalent to an observerless state reduction.

## Appendix

In the following examples taken from previous papers, the empirical verifiability of rule (1a) of the objective measurement scenario is compared with the empirical verifiability of rule (3) of the observer measurement scenario.

### An Intermediate Observer (ref. 1, eqs. 7-9)

A stochastic hit on the third or fourth component in eq. 7 could be just as easily due to rule (1a) in the objective scenario, as to rule (3) in the observer scenario. The same might be said of a follow-up hit on the third component that leads to eq. 9. There might also be a rule (1a) hit on the second component that results in a subsequent hit on the fourth component; but since the observer cannot tell the difference between this and a direct hit on the fourth component, rules (1a) and (3) are empirically indeterminate.

### An Outside Terminal Observer (ref. 1, eq. 11)

The fourth component cannot be chosen in this case because that would be an anomalous capture, inasmuch as rule (4) is in effect in *either* measurement scenario. This means that only the third component in eq. 11 can be stochastically chosen, and the observer cannot tell if the resulting reduction is due to rule (1a) or rule (3). So again, the rules are empirically indeterminate.

### An Intermediate Outside Observer (ref. 1, eqs. 12-15)

There are four potential stochastic hits in the section covering eqs. 12-15, In every case, the resulting reduction might be due to either rule (1a) or rule (3). Therefore, rules are empirically indeterminate.

Drift Consciousness (ref. 1, eq. 16)

The stochastic hit on any one of the ready brain components in eq. 16 might be due to either rule (1a) or rule (3). The rules are therefore empirically indeterminate.

Sequential Interactions with an Observer (ref. 2, eqs. 2-5)

There are three possible stochastic hits on the primed components in eq. 2, each of which might be due to either rule (1a) or rule (3). There might also be rule (1a) hits on either the second or third components that would result in subsequent hits on the fifth or sixth components; and the observer could not tell the difference between these and direct hits on components five or six. The rules are therefore empirically indeterminate.

Version I of Schrödinger's Cat (ref. 2, eq. 7)

The second component might be stochastically chosen by either rule (1a) or rule (3). The rules are therefore empirically indeterminate.

Version I with Outside Observer (ref. 2, eq. 11)

Stochastic hits on the second and third components might be due to either rule (1a) or to rule (3). All subsequent hits on these components will be on components containing ready brain states, so they too might be due to either rule (1a) or to rule (3). It follows that the rules are empirically indeterminate.

Version II of Schrödinger's Cat (ref. 2, eq. 12)

A stochastic hit on the third component in eq. 12, might result from either rule (1a) or rule (3). A rule (1a) stochastic hit on the second component would result in an eventual hit on the third component, and the observer could not tell the difference between this and a direct hit on the third component. The rules are therefore empirically indeterminate.

Version II with Outside Observer (ref. 2, eqs. 15-16)

A hit on the fourth or fifth component of eq. 16 might be due to either rule (1a) or rule (3). A primary plus a follow-up hit on the third component of eq. 16 will lead to eq. 15, and either one might be due to either rule (1a) or rule (3). There might also be a rule (1a) stochastic hit on the second component in eq. 16 that would be subsequently followed by a hit on the third or fifth component, but the observer could not tell the difference between this and a direct hit on the third or fifth component. The rules are therefore empirically indeterminate.

Version II with a Natural Wake-Up (ref. 2, eq. 19)

Direct stochastic hits on either of the components containing  $C$  or  $C_N$  might come from either rule (1a) or rule (3). There might be a rule (1a) hit on the third component that would be subsequently followed by a hit on the fourth component, but the observer could not tell the difference between this and a direct hit on the fourth component. The rules are therefore empirically indeterminate.

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