The Conscious-Unconscious Physicist experiment.

An argument for denying that consciousness collapses the wave function in quantum mechanics

Carlo Roselli

Abstract. The aim of this paper is to falsify the hypothesis that consciousness is necessary in the quantum measurement process. In order to achieve this target, I propose a variation of the *Schrödinger's cat* thought experiment called "CUP", short for "Conscious-Unconscious Physicist", in which a human being replaces the cat. The intuition *of a specific strategy has enabled me* to plan the experiment in such a way as to disprove the consistency of the above hypothesis and to oblige its supporters either to accept solipsism or to rely on an alternative interpretation of quantum mechanics in which a real world of phenomena exist independently of our conscious mind and where observers play no special role. Moreover, I have devised a complete measurement apparatus, in the sense that the CUP experiment, given that it includes also the experimenter, will begin and end exclusively within the sealed room. Hence, my analysis provides a logical explanation of the relationship between the observer and the objects of her/his experimental observation; this and a few other implications are discussed in the fifth section and in the conclusions.

Keywords: the measurement problem in quantum mechanics, mind-body problem, Schrödinger's Cat, Wigner's friend, observer's consciousness, wave-function collapse.

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1 Introduction

The orthodox (Copenhagen) interpretation of quantum mechanics (QM) does not explain how measurements take place. This omission gives rise to some awkward paradoxes (for example the *Schrödinger's Cat*)[1] which render questionable the theory's claim to completeness, unless one assumes that consciousness plays a fundamental implementation of the quantum measurement process.

Following the books published in 1932 and 1955 by the mathematician John von Neumann[1] (1903-1957) and a little book published in 1939 by the physicists Fritz London and Edmond Bauer[4], Eugene P. Wigner (1902-1995) developed an argument in favour of the above assumption, giving rise to the thesis of the wave-function-collapse (WFC) at biological-mental level, here more simply called "idealistic interpretation of QM".

This paper proposes an innovative version of the *Schrödinger's cat* experiment with the purpose of disproving the consistency of the idealistic interpretation of QM, without taking into account, in my discussion, other well-known interpretations concerning the measurement problem (see footnote 2 below).

I will use the term "idealistic" to refer to the orthodox (Copenhagen) view of atomic phenomena taken to the extreme. This view, in its turn, asserts that an elementary quantum system, say a photon or an electron, is in a state of intrinsic indeterminacy as long as it does not interact with a measuring apparatus. It also asserts that measurements can be made, but without explaining precisely how and when they take place. In other words, QM doesn't provide an explicit definition of the boundary between quantum and non-quantum mechanical systems, given that the measurement process is usually conceived as a non-quantum mechanical phenomenon.[2]

This is the main problem with the theory which weakens its claim to completeness. Indeed, the orthodox interpretation is not the only possible interpretation of QM that is subject to this problem which, in more general terms, may be considered as that of defining a satisfactory boundary – and a satisfactory transition process – between micro-systems characterized by quantum state uncertainty and macro-systems obeying the deterministic laws of classical physics[3]

Starting from the orthodox view, the *idealistic interpretation* assumes that it is the observer's consciousness the fundamental factor which is able, in some unspecified and mysterious

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[1] In his book, von Neumann[2-3] takes into consideration a causal sequence of macroscopic systems, the so called "von Neumann's chain", each of which observes the preceding one; at one end of the chain there is the quantum system followed by a first measuring device, while at the other end there is the consciousness of the observer; the link which precedes consciousness is made up of cerebral microstructures and the link preceding these is made up of various organs which are sensitive to external stimuli. Thus, arguing that quantum mechanics doesn't provide any explicit indication of where the collapse of the wave-function may occur, von Neumann can legitimately assert that it can take place at any level of the chain.

[2] The Copenhagen Interpretation, starting from a positivist conception of reality (the idea concerning the non-existence of quantities that cannot be measured), came to be interlaced with subjectivism, assuming that atomic systems are just mere possibilities and that they can achieve real existence only upon observation. In this view, only the acts of observation are real.

[3]This is a well-known point of view in the historical debate on the nature of QM. Among the first and most illustrious physicists to uphold this position (or a very similar one) were von Neumann and Wigner. From the 1940's onwards the problem of measurement has been at the centre of a lively scientific-philosophical debate: D. Bohm[2-3]; H. Everett[5]; J.A. Wheeler[6]; E.P. Wigner[7-9]; S. Kochen and E.P. Specker[10]; B.S. DeWitt[11]; W.H. Zurek[12-13]; D. Bohm and B. Hiley[14]; G.C. Ghirardi, A. Rimini and T. Weber[15]; R. Grassi, P. Pearle, G.C. Ghirardi[16-17]; R. Penrose[18-20]; D.Z. Albert[21]; H.P. Stapp[22]; M. Gell-Mann and J. Hartle[23]; C. Rovelli[24]; M. Tegmark[25]; S. Haroche[26]; A. Bassi, G. C. Ghirardi[27];; J.S. Bell[28]; J.A. de Barros and G. Oasb[29], and others. The debate on this subject has given rise to endless discussions and, so far, there has been a lack of consensus regarding which interpretation might be correct. Weber[17]; R. Grassi, P. Pearle, G.C. Ghirardi[18];R. Penrose[19-21];D.Z. Albert[22]; H.P. Stapp[23]; M. Gell-Mann and J. Hartle[24]; C. Rovelli[25]; M. Tegmark[26]; S. Haroche[27]; A. Bassi, G. C. Ghirardi[28];G. C. Ghirardi[29] ; J.S. Bell[30]; S. Yu, D. Nikolic[31], and others. The debate on this subject has given rise to endless discussions and, so far, there has been a lack of consensus regarding which interpretation might be correct.

manner (Wigner refers to "a deus ex machina")[11, p.188], to collapse the quantum system down into one only of its possible states. Here *consciousness* would not be playing a merely passive role in the measurement process, but would be the only factor capable of determining the transition from the ambiguous realm of potentials to the unequivocal realm of actual events. This is the kind of vision I mean when referring to the idealistic interpretation of QM.

By its very nature, the idealistic interpretation is difficult to evaluate, both in purely conceptual terms and, obviously, at the empirical-experimental level.[4]

The objective of the thought experiment described hereafter is to demonstrate how the idealistic interpretation of QM, also known as "consciousness causes collapse hypothesis" (CCCH) of the wave-function (WF), is forced to conclusions incompatible with the assumption that consciousness is necessary for providing a complete explanation of quantum measurement process.

2 The CUP experiment

In this section I will propose an experiment, in which a male Physicist named "**P**" is inside an impenetrable room. For all intents and purposes, the room is a so-called perfectly isolated system. In a sense, **P** will play the role of Schrödinger's cat in the original experiment, but – as will be seen – he will have, in my view, a much more important role.

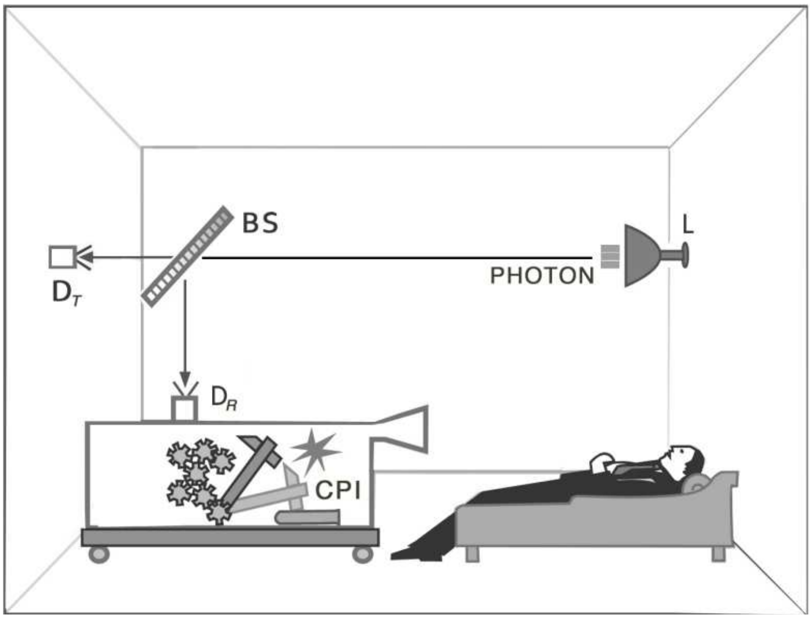

Fig. 1: the experimental room in which **P** is under the **CPI** effect in the interval of time between 1:00 and 3:00 PM.

On the wall behind **P** (see figure 1) there is an apparatus, L,[5] programmed to emit at a precise time a photon in the direction of a beam splitter, BS, inclined at 45°. Beyond the BS, along the direction of the transmitted photon, there is the detector D_T, while along the direction of the reflected photon there is the detector D_R, placed on top of a box, connected to a hammer; the hammer is connected to a light switch and under it there is a vial containing a dose of a particular substance called "**CPI**" (Conscious Perceptions Inhibitor), crucial to the experiment. The **CPI** acts as a powerful narcotic and its effect is 100% guaranteed: once inhaled by a human being, a heavy coma-like sleep is induced, but with no physical damage; simply, all conscious perceptions are completely suspended.

[4]Actually, neither von Neumann nor Wigner ever explained how it is possible for something of non-physical nature to produce a physical effect like the collapse of a quantum system.

[5]In such a mechanism a battery is supplying electric power.

The experiment is planned as follows:

1. L will emit a photon at 2.00 PM.
2. **P** has deliberately narcotized himself one hour beforehand, at 1.00 PM, with a dose of **CPI** guaranteed to induce a heavy sleep for two hours and he will regain consciousness precisely at 3.00 PM; I say precisely at 3:00 PM, but I mean "precisely" when you can claim that **P** is no more under the **CPI** effect.
3. The quantity of **CPI** contained in the vial will be sufficient to ensure two hours of heavy sleep; thus, if D_R registers, the hammer will be unhooked, the light switched on, the vial with the **CPI** shattered, **P** unconscious until before 4.00 PM.

Let us now briefly consider how the quantum theory describes the experiment: the photon is emitted from L, it collides with BS at 2:00 + Δt_1 PM (where Δt_1 is the travelling time of the photon from L to BS) and splits in two beams, one transmitted, *T*, moving along the direction of the detector D_T, and the other reflected, *R*, moving along the direction of the detector D_R, with a probability amplitude (in our example) of $1/\sqrt{2}$ for the photon to be received in each of them at 2:00 + Δt_2 PM (where Δt_2 is the travelling time of the photon WF from L to D_T and D_R).

According to the Copenhagen interpretation, the WF, denoted with "ψ", is described as a linear superposition[6] of two states:

$$|\psi\rangle = (|\text{photon } T> + |\text{photon } R>)/\sqrt{2} \qquad (1)$$

until the instant in which a measurement process takes place. This is the instant in which the WF collapses and only one of the two possible states becomes an actual outcome.[7]

If one assumes, as Wigner[9, p. 181 and p. 187], "the existence of an *influence* of consciousness on the physical world" and that "the measurement is not completed until a well-defined result enters our consciousness", that is until the WF collapses down into either one of its two component parts, then inside the room there is not one unique defined state as long as **P** is under the **CPI** effect, but rather *a linear superposition* of the two states described above which, while time is passing, is propagating along the whole macroscopic measurement system up to the scale of **P**'s brain. Then, the superposition will cease to be linear when it reaches **P**'s consciousness.

Consequently, there are two possibilities or chains of events, which are here called $E_{(T,\,R)}$ and which will travel according to the superposition principle until a certain instant of the experiment:

- E_T: *T* (transmitted part of the wave function), D_T registers, the room in the dark, the vial intact, **P** will be conscious precisely at 3:00 PM. I say precisely, but I mean 'precisely' when you can claim that **P** is no more under the **CPI** effect.
- E_R: *R* (reflected part of the wave function), D_R registers, triggers the hammer, the light is switched on, the vial is shuttered, the **CPI** spreads out, **P** will be *unconscious* until before 4:00 PM;

thus, a *complete measurement apparatus* will be available, in the sense that this experiment, given that it includes also the experimenter, will begin and end exclusively within the sealed room.

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[6] A superposition of states can never be observed, since the system collapses to a single state at the instant that a measurement takes place.

[7] As well known, in QM experiments, the probabilities of measuring one or the other of two alternative outcomes are effectively the same calculated through formal procedure, according to the wave-packet reduction postulate based on the Born rule (introduced by Max Born); this rule, although being one of the most mysterious principles in quantum physics, is quite simple: it states that the probability of obtaining each of the possible outcomes is equal to the square of the corresponding amplitude. In our example the WF is the set of the two amplitudes described in equation (1), hence the probability is ½ for both alternative outcomes.

3 Formal description of the CUP experiment

. All supporters of the CCCH may believe that *any* QM experiment, no matter whether applied to a cat or to a human being, must in the end give rise to the same conclusions drawn by Wigner from his thought friend's experiment and from his additional, and stronger, hypothesis [11, pp.185-196] concerning the role of consciousness in the quantum measurement process.

In discussing the CUP experiment described in section 2, we put ourselves in Wigner's place in order to verify whether or not there are the conditions for **P**'s consciousness to bring about the collapse of the WF.

To this end, in the interval of time between 3:00 and 4:00 PM the WF $|\psi\rangle$ of the experiment, according to the standard formalism of quantum mechanics, will be described as follows:

$|\psi\rangle$ = (|D_T registers> |the room in the dark> |**P** *conscious* at 3:00 PM> + |D_R registers> |the room in the light> |the hammer shatters the vial> |the **CPI** spreads out> |**P** *unconscious*>)/√2 (2)

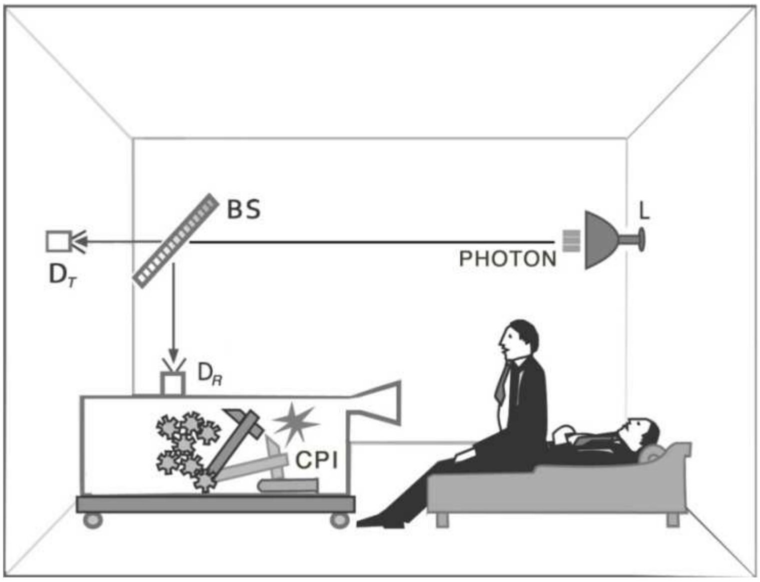

Fig. 2: the Copenhagen interpretation of QM does not explicitly preclude a description of **P** in the superposition of states |*conscious*> + |*unconscious*> in the interval of time between 3:00 and 4:00 PM

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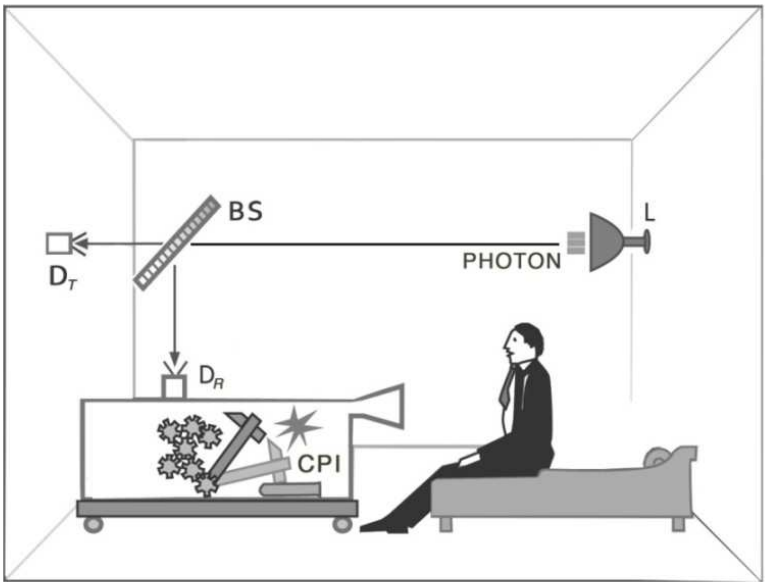

Fig. 3: at the latest and with probability 1/2, **P** will be conscious in the light precisely at 4:00 PM.

3.1 Three remarks regarding the experiment

(i) - The expedient of the **CPI** has a fundamental function. In fact, supposing that its first dose were not used, according to the CCCH **P** would cause the collapse of the WF precisely as soon as he realizes whether or not he is inhaling a second dose of **CPI**.

(ii) - Equation (2) describes a quantum superposition of two distinct macroscopic states in the interval of time between 3:00 and 4:00 PM: | **P** *conscious*> + | **P** *unconscious*> (figure 2). Note that, under the CCCH, the collapse of the WF requires that one of its two branches be eliminated by someone's conscious observation, but in this experiment, as already mentioned at the end of section 2, **P** is the only observer.

(iii) - Human beings have access to their own internal states, perhaps similarly to cats or other animals, but, differently from these, they have the faculty of making very sophisticated analytical thinking due to their cumulative culture.
Here is the room at 4:00 PM.

4 The CUP experiment disproves the consistency of the CCCH

P will be suddenly conscious either in the dark (thus at 3:00 PM) or in the light (thus at 4:00 PM).[8]

Could **P** think possible that it has been his act of conscious observation to cause the collapse of the WF into one of the above possible outcomes? He reflects for a while before providing an appropriate answer.

Since the CCCH implies by definition a causal connection between two phenomena, i.e. "the observer's consciousness" and "the WF collapse", **P** will examine whether, in the context of his experiment, there is a way to disprove the former as a causal agent of the latter**.** Hence, in order to achieve his goal, **P** will adopt a line of reasoning putting forward two relevant points:

First, when one considers any QM experiment, particularly Schrödinger's cat, Wigner's friend or similar versions, it is evident that the experimenter, in order to acquire knowledge of the actual outcome, has to perform an intentional observation/measurement that, according to the CCCH, collapses the wave function and, therefore, the observer's consciousness is supposed to play an active role on the physical world situated outside her/his mind.

Still, it is clear that the above point does not fit the CUP experiment simply because **P**, in view of the introduction of the **CPI** stratagem, plays a *passive* role. In fact **P**, as soon as conscious either in the dark, thus at 3:00 PM, or the light, thus at 4:00 PM, is neither in the same situation of the observer who deliberates to open the Schrödinger's box for verifying the state of the cat, nor in the same status of attentiveness of Wigner's friend[9] when checking whether he did perceive a flash or did not.

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[8] This experiment has been devised in such a way that, on the one hand, the state '**P** regains consciousness in the dark' equivalent to the state '**P** regains consciousness precisely at 3:00 PM', while, on the other hand, the state '**P** regains consciousness in the light' is equivalent to the state '**P** regains consciousness precisely at 4:00 PM',

[9] Wigner's friend, here called "**F**", is a physicist left alone inside a laboratory with the task of checking *attentively* whether or not a detector has emitted a flash (has registered the arrival of a photon or not). Wigner is waiting outside and suspects that **F** (as well as all other human beings) may have weird perceptions and be in the superposition of macroscopically distinct states |**F** has perceived a flash> + |**F** has not perceived a flash>. Finally, Wigner enters the lab and asks **F** whether or not he perceived a flash. His reply (yes or no) should remove any doubt as to whether the wave-function collapse has occurred. However, Wigner will question whether it is acceptable or not to establish that the collapse into one only of the two possible alternatives is determined by his action (his request and reception of an unambiguous answer). He poses this question since his initial way of interpreting the state of the system gives rise to a rather embarrassing paradox, from which he has three possible ways of escape: 1) accept a relative form of *solipsism*, in the sense that he believes to be, among all living creatures, the only one who has unambiguous perceptions, 2) assume that QM is an incomplete theory, 3) assume that QM is not applicable to human beings; he refutes solipsism and, being a firm supporter of QM completeness, opts for the last solution, assuming that there are beings, at least human beings, endowed with *consciousness* that constitutes an ultimate reality and plays an active role in determining the measurement process by rules that are not susceptible to scientific description.

Second and crucial argumentation: if you are a supporter of the CCCH and claim, for example, that the collapse occurs precisely when **P** regains consciousness in the dark, i.e. at 3:00 PM (or in the light, i.e. at 4:00 PM), you will be led to conclude that the two events - the appearing of **P**'s consciousness and the WF collapse, thought to be the *cause* and the *effect* respectively - occur simultaneously:[10] between cause and effect no time elapses.

But reflecting on this incautious conclusion, **P** can understand that your conviction is based on the wrong impression that, as soon as **P** becomes conscious in the dark (at 3:00 PM), there are the *two above distinct events* occurring simultaneously, while at that time, indeed, *only one event* takes place: that is the fortuitous actualization of the state '**P** conscious in the dark'.

This wrong impression, if not grasped as such, gives rise to irrational assertions. In fact, as soon as he enters the state 'conscious in the dark', **P** finds it illogical your belief that his consciousness causes the collapse of the WF into the *same* state that **P** is entering.

According to our logic, causality is a relationship through which one event A (the cause) gives rise to something else, B (the effect). Therefore, the idea (emerging from the above assertion) that the event A gives rise, as effect, to an event that is the same as A, has to be rejected as an absurdity. Also the quantum superposition of the two distinct macroscopic states shown in Eq. (2) has to be rejected in favor of a statistical mixture of states, '**P** conscious' or '**P** unconscious'.

Finally, **P** is now certain that his consciousness cannot be the *cause* of the collapse. Instead, this is exactly the case in which the appearing of his consciousness must have been the *effect* resulting from the collapse of the WF occurred long before, reasonably when either D_T or D_R registered the arrival of the photon.

Summing up, given the state '**P** conscious in the dark' or the state '**P** conscious in the light', that's it! That is simply the o*utcome* acknowledged by **P** after the CPB effect is gone.

5 Conclusions

All the above considerations have led me to conclude that, in this experiment based on the **CPI** stratagem, the *collapse* of the WF can neither take place at 3:00 nor at 400 PM. That is to say that the collapse *is independent of the observer's consciousness* and that the CCCH, as explained in the previous section, is logically inconsistent, despite a recurring conviction that it is not falsifiable; see for example J. Acacio de Barros and Gary Oas[28].

If my analysis is accepted as well-grounded, a supporter of the idealistic interpretation of QM, say **W**, could still believe that it has been **P**'s act of conscious observation to cause the collapse of the WF, no matter whether he regained consciousness in the dark or in the light; but in this case **W** would be trapped in *solipsism.*[11]

Thus, starting from a rebuttal of solipsism as undesirable in science, one has to rely on an alternative interpretation of QM, in which the role of the conscious observer, who is required in all scientific experiences, is merely relegated to acknowledge the experimental results. We immediately understand that these conclusions have further implications, such as:

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[10] The question of causality is problematic, since it requires a distinction between the subjective and the objective aspects of this concept. Causality entails another (arguable) question called "cause and effect simultaneity", which has been discussed and investigated in depth by several philosophers, such as I. Kant, D. Hume, G.W. Leibniz and, recently, by Donald Gillies, Jay F. Rosenberg, Sylvain Bromberger et al.; for a detailed understanding see Buzzoni M.: *The Agency Theory of Causality, Anthropomorphism, and Simultaneity*, section 6, published online: 29 Jan 2015, https://doi.org/10.1080/02698595.2014.979668.

[11] There are two different forms of solipsism: one is described in note 2 as a relative solipsism, the other (associated to an inflexible belief in the CCCH) would lead to an absolute solipsism, that is to say "I believe to be the only thinking entity, while an external reality (including my body), being a product of my mind, does not exist objectively.

(**a**) - the concept of "collapse of the WF independently of consciousness" emerges from the *logical structure* of my thought experiment based on the **CPI** strategy, since it allows to see in a new light the relationship between subject and object of observation (as explained in section 4);
(**b**) - if it were not conceivable an experiment such as the CUP, capable of disproving the CCCH, this latter would still represent a possible and, for a few physicists, an even more suitable alternative to other interpretations of quantum mechanics.
(**c**) - in the realistic QM theories based on the collapse postulate, *the* boundary between quantum and classical systems should now be reasonably *rescaled down* to the transition point between the quantum system described in (1)] and the initial (uncertain number of) atomic components of the photo-detector with which it interacts at 12:00 + Δt_2 PM (where Δt_2 is the travelling time of the photon WF from L to D and D');
(**d**) - in the collapse theories *Schrödinger's cat* experiment can no longer be considered a paradox: before opening the box, the cat (as well as **P** in the CUP experiment) is in a statistical mixture of states, 'dead' or 'alive';
(**e**) - the falsification of the CCCH rules out also the hypothesis that the collapse of all the wave-functions involved in our Universe (according to the hypothesis shared by many scientists that consciousness is regarded as an emergent phenomenon) occurred when the first conscious human being appeared in it, thus avoiding to render the big-bang a senseless theory;

In synthesis, the starting point of my work is that the idealistic interpretation requires the superposition of macroscopically distinct states as well as the conscious perceptive faculty of the observer. This is necessary for consciousness to play a fundamental role in the collapse of the WF.

Nevertheless, it is possible to devise at least a thought experiment (e.g. the CUP), which disproves the hypothesis that it is the observer's consciousness that causes the collapse. If this is shared as logically compelling, then one is left with the immediate issue of what the best alternative to the idealistic interpretation should be, and clearly this is an entirely different (and daunting) problem.

However, I feel that the ordinary idea behind the CUP experiment is that there are two ingredients, given by the *wave function* and the *conscious state* of potential observers, which cannot in general be clearly separated, at least in such a way as to make the latter a causal agent in the collapse of the former. If this is true, then a fruitful way to tackle the measurement problem can only be one that treats the above two ingredients in a single coherent framework.

Recent advances in the quantum de-coherence and a re-examination of Everett's Many Worlds Interpretation suggest that such a framework could be constructed entirely within the boundaries of the theory itself; see, for instance, Roland Omnès[29], Maximilian Schlosshauer[30] and David Wallace[31], but clearly this is not the only route; see also Bernard d'Espagnat[32] and the very recent works of Carlo Roselli. Bruno R. Stella[33] and Art Hobson[34-35].

Furthermore, the CUP experiment could represent a good reason for strengthening some of the actual quantum mechanical spontaneous localization models, where observers have no particular role: I am referring to Ghirardi, Rimini and Weber theory (GRW), to Penrose and to Hameroff-Penrose interpretations, in which the WF is assumed to be as a physical reality and its collapse as an objective dynamical process, that in Penrose's approach is supposed to be induced by gravity.

I would like to close this paper quoting the following words of Steven Weinberg[36, p. 124]:
"*I read a good deal of what had been written by physicists who had worried deeply about the foundations of quantum mechanics, but I felt some uneasiness at not being able to settle on any of their interpretations of quantum mechanics that seemed to me entirely satisfactory*".

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