A deconstruction of "EPR paradox"

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ABSTRACT. The aim of this paper is simple and essential: trying to undo the fast web between philosophical assumptions and scientific propositions enveloping foundations of Quantum Mechanics. This approach may lead towards the dissolution of some pseudo-problems.

RESUME. Le but de cet article est aussi simple qu'essentiel: essayer de démêler le réseau serré des hypothèses philosophiques et des propositions scientifiques qui enveloppe les fondements de la mécanique quantique. Cette approche peut amener la disparition de certains pseudo-problèmes.

1. Introduction

In this paper I do wish neither to propose new physical results nor "astonishing" philosophical interpretations. Instead, I would like to dissipate fogs which surrounded foundations of Quantum Mechanics.

Many, even if not all, of the so-called paradoxes of Quantum Mechanics and the related misunderstandings have risen because the philosophical beliefs of physicists and philosophers are brought into the game. Thus, learning to enucleate them is a step towards the solution of some problems.

I will try to show how this result may be reached by splitting what belongs to a physical domain from what belongs to a philosophical domain. Therefore, I will take into consideration one of the classical moments of the discussion: the 1935 Einstein-Podolsky-Rosen [from now on, EPR] paper and the Bell's work on his well known inequalities.

2. Images and intuitions of the world

I begin this attempt by constructing the necessary tools. The first step is given by remembering that, according to Hertz, a piece of nature can be reconstructed by more than one formal non-selfcontradictory and empirically correct "image" (*Weltbild*)[1].

The image tries to approximate reality as much as possible, even if it does not capture the latter like a photograph. It tries to be a verisimilar reformulation of it; a detailed and precise "how" characterised by the fact "that the consequents of the images must be the images of the consequents"[2].

An image of the world tells us *how the world is*. Therefore, it must agree with this world that, in such a way, becomes its true and unique (even if non incontestable, as history and philosophy of science teaches us) court of justice.

If the *Weltbild* is a formal reconstruction of the world, the intuition of the world (*Weltanschauung*) aims at, and is afferent to, an epistemologically higher task. The *Weltanschauungen* give a sense to the world. The *Weltbilder* enclose the sense of the world in brackets, even if they are in close contact with the empirical reality and even if they depend on it as for their epistemological validity. They do not deal with it. They do not treat with it. This is the domain of the intuitions of the world.

Each physical *Weltbild* is part of a given *Weltanschauung*, nay it can be part of many more *Weltanschauungen*, which could be also not completely compatible among them. Anyhow, not each *Weltanschauung* necessarily implies a *Weltbild*. This need is given only inside scientific knowledge, in fact physical knowledge.

The intuitions tell us *that the world is* [3], rather than *how the world is*. Such intuitions, as said, imply an assignment of sense to the world. This assignment of sense is due to the acceptance of the values and the metaphysical principles, that are inside the intuitions themselves, by the physicist who adopts them [4].

Each *Weltanschauung* contains metaphysical principles on the world and ethical, aesthetical, epistemological values. All this permits to speak about assignment of sense to the world.

Even more, the intuition allows not only to give a sense to the world, but also to the images which formally reconstruct such a world. Interpreting an image in an instrumentalistic, or conventionalistic, or

operationalistic way means nothing but seeing it through eyes moulded by a given *Weltanschauung*.

Thus, the main role is played by the *Weltanschauung*. All goes around it and all depends on it or, better, on the metaphysical principles (about the world), on the epistemological principles (about the images which try to capture such a world) and on the values by which it is made up.

Therefore, each physicist works with *Weltbilder* on *how the world is*. Moreover, each physicist works also within a *Weltanschauung* through which he gives a sense to the world and its images. That is, each physicist, willy-nilly, takes side on that *the world is* and that *the images of the world are*. Each physicist gives a sense to the object of his research and to the images by which he tries to capture it. Each physicist, being a man, works, acts, creates, lives because he does have a *Weltanschauung*.

As said, if the criticism to an image is such to be essentially empirical, this is not valid in case of an intuition of the world. Now we do not deal any longer with formal reconstructions trying to capture reality and, therefore, they can not be judged (and so refuted or corroborated) by this latter. Now we are dealing with metaphysical principles, with beliefs, with values.

3. The reference to values

From this, it follows immediately that in every discussion on foundations of Quantum Mechanics the images (*Weltbilder*) should be separated from their philosophical and epistemological interpretation, i.e., from the *Weltanschauungen* in which they are embedded. In the first case, as Hertz pointed out, the logical and empirical coherences have to be discussed. In the second, as I am trying to show, *the discussion should be about the metaphysical beliefs which can not be rationally demonstrated but only rationally argued.*

The difference between demonstration and argumentation is given [5] by the fact that the first is made within a closed and univocal system, in which problems of interpretation and choice have been eliminated from the beginning. Whereas the second refers to a set of premises each of which can be discussed. *Demonstration* presumes a process by which the proposition, which has to be demonstrated, is deduced from the proposition by which it is conditioned, and where this latter is conventionally thought valid without discussion. *Argumentation*, instead, is a process

aiming at justify a proposition which is not conditioned by any other, being itself the ultimate condition.

It follows that even if no metaphysical belief can be demonstrated to be absolutely true or absolutely valid, each one can nevertheless be argued.

Therefore, if no intuition of the quantum world can be founded on *fundamenta inconcussa*, how may we choose one instead of another? Max Weber would have answered the question affirming that each choice is made by a *Wertbeziehung* [6], that is by reference to a set of values. The subject of the knowledge (i.e., the physicist) chooses to work inside -or with- a certain intuition of the world by referring to the values he believes in, as an individual subject.

Believing in the validity of a specific interpretation of Quantum Mechanics is believing in the values of the *Weltanschauung* associated with such an interpretation [7].

4. The 1935 Einstein, Podolsky, Rosen paper: a textual analysis

After having constructed the critical tools, the classical EPR paper can be analysed. It is worth noting that M. Jammer [8] singles out two philosophical presuppositions which are explicit in the paper and two which are mentioned only *en passant*. But there are more than four. I will try to enucleate them following the text step by step.

1) "Any serious consideration of physical theory must take into account the distinction between the objective reality, which is independent of any theory, and physical concepts with which the theory operates" [9]. This is a presupposition according to which an external reality exists and it is not only independent of the subject of knowledge (metaphysical presupposition stating an ontological realism), but also of any theory (epistemological presupposition on the theory-world relationship stating that the theory does not construct the world).

2) "It is only in the case in which positive answers may be given to both of these questions ["Is the theory correct?", "Is the description given by the theory complete?"], that the concepts of the theory may be said to be satisfactory" [10]. This is an epistemological criterion of validity, according to which a theory is satisfactory if, and only if, it agrees with the experience and if it is complete. This criterion involves the epistemological presupposition on the structure of the theories stating that these must be complete.

3) "The elements of a physical reality cannot be determined by a-priori philosophical considerations, but must be found by an appeal to results of experiments and measurements" [11]. Whereas at point 1) EPR state that reality is independent of theories, here, beside confirming its independence from any philosophical assumption (but isn't this a philosophical assumption, too?), they say that its elements may be found experimentally. This is a corollary to the presupposition about the theory-reality relationship.

4) "If, without any disturbing a system, we can predict with certainty (i. e., with probability equal to unity) the value of a physical quantity, then exist an element of a physical reality corresponding to this physical quantity" [12]. This is a (only sufficient) criterion of reality that, according to EPR, agrees with the idea of reality of both Classical and Quantum Mechanics [13].

5) "On the other hand, since at the time of measurement the two systems no longer interact, no real change can take place in the second system in consequence of anything that may be done to the first system" [14]. This is a metaphysical presupposition about the structure of the world. It is the principle of separability.

6) The results of Quantum Mechanics have to be thought of to be valid [15]. This is a pragmatical consideration which is implicit in the text and which is connected with the great experimental success of the theory.

5. The EPR Weltanschauung

Sum up the metaphysical and the epistemological principles assumed by EPR:

i) Presupposition about the external world:

A. "An external world exists".

ii) Epistemological presuppositions about the theory-reality relationship:

B1. "The theory does not construct the external world";

B2. "Elements of such a world are given (and not made) only by means of experiments";

B3. "The theory touches an element of reality when it succeeds in predicting with certainty the value of the corresponding physical quantity without disturbing the system".

iii) Presuppositions on the general structure of the theories:

C1. "A theory has to be complete";

C2. "A theory is satisfactory if, and only if, it is complete and empirically correct".

iv) Presupposition on the general structure of the world:

D. "Reality is separable".

Given A; B1, B2, B3, C1, C2 and D form the basis of the EPR *Weltanschauung*, Wg(EPR) and so of their interpretation of the quantum *Weltbild*. But not only. EPR, in such a way, have also established a) an epistemological research programme (founded on B1, B2, B3, C1, C2) aiming at the search of complete and correct theories and b) a scientific research programme (given by D) aiming at a theory which agrees with a world characterised by separability. EPR suggest that these research programmes could also lead towards the construction of a quantum image which is different from the "orthodox" one [16].

Therefore, it seems clear that the EPR criticism, made to the "orthodox" [17] interpretation of Quantum Mechanics, is not purely formal, but it starts from an intuition of the quantum world (from a *Weltanschauung*) which is incompatible with it, as will be seen.

We have said that a same piece of nature may admit various formal *Weltbilder*: Wd1, Wd2, Wd3, ..., and each may admit infinite interpretations: I1(Wdi), I2(Wdi), I3(Wdi), ...

EPR, in their paper, take the "orthodox" image Wd(o) into account and they emphasise that this is also characterised by the fact that (F) when two operators are not commuting, the corresponding physical quantities cannot be simultaneously measured with absolute precision. Then they "read" such a Wd(o) with the hermeneutic pre-comprehension (*die Vorverständnis*) [18] given by their interpretation I(EPR), which is supported by their Wg(EPR).

Reading Wd(o) with the pre-comprehension I(EPR), especially through the presupposition B3, means that the above formal characterisation F becomes the following assumption on the theory-world relationship: (F') "When the operators corresponding to two physical quantities do not commute the two quantities cannot have simultaneous reality" [19].

After having specified F', EPR show that this one is in contradiction with the assumption C1. Therefore, *aut* F' is valid, *aut* C1 is valid. They demonstrate that, given F', C1 is not satisfied by the image Wd(o) and so, for C2, that this latter is not complete.

As a matter of fact, *EPR have reached only the conclusion that Wd(o) is not satisfactory if it is read through I(EPR) and not that Wd(o) is always unsatisfactory!* In fact, there may be interpretations I≠I(EPR) which permit reading Wd(o) and which find it satisfactory. For example, Wd(o) is satisfactory if read through the "orthodox" interpretation I(o), which has different criteria of reality and epistemological validity.

The Wd(o) image is not satisfactory, according to EPR, from a philosophical point of view which presumes certain specific metaphysical and epistemological assumptions and not from a formal one. Only starting from the first, affirming that Wd(o) is not complete is possible. Therefore, either it has to be modified, (maybe by introducing the so-called "hidden variables" to obtain a version Wd(o')), or it has to be changed for a totally different image Wd(α) [20]. In this way EPR have outlined the track for the construction of Wd(o') or Wd(α), on which many physicists and philosophers of physics are working at present. But are these aware that, in such a way, they are supporting I(EPR)? Have they philosophically thought about the presuppositions of Wg(EPR)?

6. The relativity of Weltanschauungen and the quantum paradoxes

The so-called EPR paradox exists only for those who accept seeing the world with eyes moulded by Wg(EPR), and not for those who possess different *Weltanschauungen*. Specifically, the paradox survives only by accepting B3, C1 and D.

EPR are aware of this, at least as regards to B3. In fact, they said that if it were chosen a criterion of reality different from B3 things would change.

This is the case, for example, of a criterion like B3': "Two or more physical quantities can be regarded as simultaneous element of reality only when they can be simultaneously measured or predicted" [21]. Nevertheless, EPR refuse such a possibility on the grounds of a peremptory, but epistemologically unjustified, statement: "No reasonable definition of reality could be expected to permit this" [22].

In reality, they only want to refuse the validity of any interpretation I≠I(EPR), like the one containing B3' instead of B3. Actually, they are making a rhetorical attempt to argue in favour of their intuition about the quantum world.

Let's try to schematise what said. If Wd(o) is "read" by I(o), we have: i) there is no incompatibility; ii) there is no paradox; iii) one can

continue to work with this Wd(o). On the contrary, If Wd(o) is "read" by I(EPR), the matter completely changes: i) there is incompatibility; ii) there is paradox; iii) one searches for Wd(o') or Wd(α).

$$\text{Wd(o)} \begin{cases} \text{read by I(o) associated with Wg(o)} \Rightarrow \begin{cases} 1 & \text{There is compatibility} \\ 2 & \text{There is no paradox} \\ 3 & \text{One continues to work with Wd(o)} \end{cases} \\ \text{read by I(EPR) associated with Wg(EPR)} \Rightarrow \begin{cases} 1 & \text{There is incompatibility} \\ 2 & \text{There is paradox} \\ 3 & \text{One searches for Wd(o') or Wd}(\alpha) \end{cases} \end{cases}$$

Therefore the real problem, taking place at the level of the comparison among *Weltanschauungen* by which the microscopic world receives sense, is of philosophical nature. Certainly, it is not of formal nature, as many persist in upholding, embroiling even more, in such a way, the matter.

7. Are the EPR presuppositions valid?

Now examine the presuppositions assumed by EPR. In this way it will be found that not all are philosophically correct and unambiguous.

EPR start from the realistic presupposition A which is valid, but for the same reasons by which an idealistic presupposition should be valid, too [23].

The choice of B3 is valid, but one should be aware of its epistemological relativity. There is no rational possibility of choosing between A and a A'$\neq$A, or between B3 and a B3' = B3 in an irrevocable and decisive way. The choice is always made by means of the only authority in this situation: the reference to values.

However, the assumptions which are philosophically suspect are B1 (the theory does not construct any elements of reality) and B2 (elements of reality may be empirically found).

Does this mean that reality is independent of the theory, but empirically knowable? Does it exist, perhaps, in the form of noumenic reality (untouchable by the theory but only by the measuring apparatus)? How may this be possible, if all experimental apparatus and all experiments are impregnated with theory? Moreover, even if it were so, the noumeno, the absolute truth, would be approached every time an experiment were carried on . But this is impossible, as history of science teaches us.

Is, perhaps, the independent reality, which EPR speak about, a third kind of reality? Does it, perhaps, exist another reality, beyond the unknowable noumenic reality and the phenomenal one?

Do, perhaps, EPR intend that reality is independent of Quantum Mechanics? But, why only from Quantum Mechanics and not, for example, from Classical Mechanics or Special Relativity?

It is easy to understand that affirming that reality is independent of the theories but experimentally knowable, is claiming something ambiguous and not completely correct from a philosophical point of view.

Perhaps, some physicists or philosophers of physics will tax the above with sophism. They can, if they wish; they can anathematize it [24], but this is not philosophically sufficient to discard it.

8. Bell's inequalities and the two level of reality

In 1935, EPR tried to demonstrate the incompleteness of Quantum Mechanics. Almost thirty years later, in 1964, Bell shifted the attention from this topic to the one of the separability, according to which "the result of a measurement on one system be unaffected by operations on a distant system with which it has been interacted in the past" [25].

He demonstrated that the "orthodox" *Weltbild* of Quantum Mechanics, which connects the phenomena in a non-separable way, Wd(ns), leads towards empirical conclusions which are different from the ones deduced from the quantum *Weltbilder* which connect the phenomena in a separable way, Wd(s). It follows that it is possible planning an *experimentum crucis* able to definitively settle the question.

Separable reality is spoken about, but what "reality? If the discussion were at an ontological level the question should be: "Is reality in itself separable?". Unfortunately, this is asking something about an entity which, due to its intrinsic nature, can not be known. No one can affirm with absolutely rational certainty that reality in itself is separable or non-separable. No one, a fortiori, can experimentally settle the question.

The dilemma of whether reality in itself is separable or not is a modern antinomy that Kant, if he was still alive in the present days, would have correctly included in his *Die transscendentale Dialektik* together with the canonical four antinomies [26]. Trying to solve the dilemma of separable/non-separable, at this ontological level, is not to make metaphysics but to mystify or, as Kant would have said, to make hyperphysics.

Moreover, as it is a question involving reality in itself, it has nothing to do with the physical theories constructed by the human subject. These concern only the phenomenal reality. Therefore, not only those who affirm that reality in itself is separable (or non-separable) have to take into account a sort of Kantian antinomy, but, if they tried to solve it by means of Quantum Mechanics, they would fall into the fallacy of ingenuous realism.

Passing from the ontological level to the phenomenal one, it rises another possible source of confusion.

In fact, although every image may have many (infinite) interpretations, not all the interpretations are consistent with the same image. Therefore, I(s) is one of the infinite interpretations which is consistent with Wd(s) and, likewise, I(ns) is consistent with Wd(ns); but I(s) is not consistent with Wd(ns) and I(ns) is not consistent with Wd(s).

So, whoever, on the grounds of his reference to values, believes that I(s) is valid, will not consider valid to work with Wd(ns). Vice versa for whoever considers I(ns) valid.

9. The epistemological place of Bell theorem

Coming back to Bell theorem, it is, obviously, not situated at the hyperphysical level nor at the metaphysical one, but at the one pertaining to images.

Here it is sufficient to recall that Bell, taking again the EPR argument as thought out by D. Bohm [27], shows that some fundamental inequalities can be reached by working inside Wd(s), whereas this result can not be obtained within Wd(ns). Therefore, if an experimental result infringes the inequalities, it follows that Wd(ns) is valid; otherwise, Wd(s) is valid.

Thus, it was possible to realise experiments in order to settle the question and from these an infringement of Bell inequalities was found [28].

I omit discussing what the 1969 revision of Bell theorem epistemologically means, but I will dwell briefly on the violation.

A well-established epistemological result says that experience is neither something independent of theories, nor, *a fortiori*, something which has to do with the noumeno. It is something constructed by scientific theories, i.e., by *Weltbilder*. Therefore, experience is not something equal

for all ages and cultures, but something changeable and contextually constructed.

If experience negatively answers the Bell inequalities, it means that the theoretical non-separability (constructed within Wd(ns)) agrees with the empirical non-separability (constructed by Wd(ns) itself and by the background knowledge *Weltbilder*). This agreement, on the contrary, does not exist between theoretical separability (constructed by Wd(s)) and the empirical separability (constructed by Wd(s) itself and by the background knowledge *Weltbilder*) which someone hoped to find.

Only this is said by the empirical results: neither that ontological reality is non-separable, nor that non-separable theories have to be searched for. Experiments touch neither the level of metaphysical presuppositions (the one of the interpretation), nor the level of methodological norms (the one of research programmes).

To conclude, it is useful to remember that some physicists [29] do not deny the negative results, but deny that they are crucial. Acting in such a way means recovering, perhaps being unaware, the epistemological dispute on the possibility of the *experimentum crucis* which was opened in 1914 by P. Duhem [30]. He thought that a negative result could not ever definitely and directly falsify a theory. As it is connected, directly and indirectly, with the totality of knowledge, it is impossible -Duhem said- to affirm that the negative empirical *instantia* falsifies the theory.

It is undeniable that a theory is connected with the rest of knowledge. Analogously, it is undeniable that also the experimental apparatus and the experience are such. But, here, trust enters the play. The arrows of the Popperian *modus tollens* [31] will be directed against those parts of knowledge which we trust less. So, whoever greatly trusts Wd(s) (or I(s)), will deny considering as falsified this approach. Vice versa, whoever trusts Wd(ns) (or I(ns)) will accept with joy the negative experimental results and will consider them as falsifying the opposite ways of seeing things. *This is only a matter of trust, belief, values.*

10. Conclusion

From the above analysis, it follows that the problems on foundations of Quantum Mechanics can not be solvable in a purely formal way. The greater part of the knots are philosophical and even if they can not be entirely resolved, owing to their metaphysical character and due to the limit of human reason, they can be all correctly framed.

What makes the matter complex and practically inextricable is the confusion between metaphysical level and scientific level, between demonstrable and arguable, between the quantum formal image (Weltbild) and its interpretation (*Weltanschauung*).

Facing the problem of foundations of Quantum Mechanics is an operation which should be done with sharp blades used by able surgeons and what above would be one of these blades.

References

[1] H. Hertz, *The principle of mechanics*, engl. transl. by R.S. Cohen (Dover, New York, 1954), pp. 1-4.

[2] Ivi, p. 4.

[3] With reference to the difference between "how the world is" and "that the world is", cf. L. Wittgenstein, *Tractatus logico-philosophicus* (Routledge and Kegan Paul, London, 1961), 6.44.

[4] By now, almost all philosophers and historians of science agree on the presence and on the relevance that non-physical, i.e. metaphysical, beliefs have on physics. Cf., e.g., E.A. Burtt, *The metaphysical foundation of modern physical science* (London, 1932); T.S. Kuhn, *The structure of scientific revolutions* (The University of Chicago, Chicago, 1970); I. Lakatos, "The falsification and the methodology of scientific research programmes" in I. Lakatos, A. Musgrave (eds.), *Criticism and the grouth of knowledge* (Cambridge University Press, Cambridge, 1970); G. Holton, *Thematic origins of scientific thought: Kepler to Einstein* (Harvard University Press, Cambridge (Mass.), 1973); P. K. Feyerabend, *Against method* (Free Press, London, 1975).

[5] C. Perelman, L. Olbrechts-Tyteca, *Traité de l'argumentation* (Presses Universitaires de France, Paris, 1958), ˇ1.

[6] Cf. M. Weber, "Die 'Objectivität' sozialwissenschaflicher und sozialpolitischer Erkenntnis", *Archiv für Sozialwissenschaft und Sozialpolitik* 19(1904), 143-207.

[7] With reference to the topics of the first two sections, cf. G. Boniolo, *Linguaggio, realtà, esperimento* (Piovan Ed., Abano Terme (PD), 1990); also F. Barone, *Immagini filosofiche della scienza*, (Laterza, Bari, 1983). With reference to an approach aiming at emphasising the relationship between Quantum Mechanics and metaphysics, cf. C.A. Hooker, *Projection, physical intelligibility, objectivity and completeness: the divergent ideals of Bohr and Einstein*, Brit. J. Phil. Sci. 42(1991), 491-511.

[8] M. Jammer, *The philosophy of quantum mechanics* (J. Wiley & Sons, New York, 1974), pp. 184-185.

[9] A.Einstein, B. Podolsky, N. Rosen, "Can quantum-mechanic description of physical reality be considered complete?", *Phys. Rev.* 47(1935), 777-780.

[10] Ibid. p.777

[11] Ibid. p.777

[12] Ibid. p.777
[13] Ivi, p. 778.
[14] Ivi, p. 779.
[15] Ivi, passim.
[16] It is not easy to state without ambiguity which is the "orthodox" interpretation. An attempt towards this goal is given in H.P. Stapp, "The Copenhagen interpretation", *Am. J. of Phys.* 40(1972), 1088-114.
[18] Ref. 10, p. 780.
[19] With reference to this topics, cf. G.Boniolo, F.Gonella, "Quantum Mechanics and imagery: a hermeneutical approach", *Found. of Phys.* 21(1991), 845-854.
[19] Ref. 10, p. 778.
[20] EPR leave open this possibility: "While we have thus shown that the wave function [our Wd(o)] does not provide a complete descriptions of the physical reality, we left open the question of whether or not such a theory is possible" [Ivi, p. 780].
[21] Ibid.
[22] Ibid.
[23] Establishing the absolute truth of propositions such as "An external world exists", "An external world does not exist" belongs neither to human demonstrative reason nor to empirical techniques.
[24] There are physicists who says things such as: "*In spite of Kant* the argument [reality is independent of theories but knowable] stands" [B. D'Espagnat, *A la recherche du réel* (Bordas, Paris, 1981), ch. 7; my italics] Is not disposing of Kant with a simple "in spite of" too superficial?
[25] J.S. Bell, "On Einstein, Podolsky, Rosen Paradox", *Phys.* 1(1964), p. 195. EPR, in their paper, considered separability so obvious that they mentioned it *en passant*. In 1949, however, Einstein become aware of its importance, cf. A. Einstein, "Autobiography", in P.A. Schilpp (ed.), *Albert Einstein philosopher scientist* (Library of Living Philosophers, Evanston, 1949).
[26] i) Is the world finite or infinite? ii) Is or is not the whole divisible into simple parts? iii) Is or is not the world causal? iv) Is or is not there an ultimate cause? Cf. I. Kant, *Critique of pure reason*, engl. transl. by N. Kemp Smith (Macmillan Education, London, 1989), pp. 393-421.
[27] D. Bohm, *Quantum theory* (Prentice-Hall, New York, 1951), pp. 614-19.
[28] Owing to the lack of efficency of the detectors, no experimental apparatus could be materially realised to set the question. To overcome this difficulty an ulterior hypothesis was suggested by J.F. Clauser, H.A. Horne, A. Shimony, R.A. Holt, "Proposed experiment to test the local hidden-variables theories", *Phys. Rev. Letters* 23(1969), 880-884. However the experiment was carry out and the classic results are in A. Aspect, P. Grangier, G. Rogers, "Experimental test of realistic local theories via Bell's theorem", *Phys. Rev. Letters* 47(1981), 460-463; Idem, "Experimental realisation of EPR Gedankenexperiment: a new violation of Bell's inequalities", *Phys. Rev. Letters* 49(1982), 91-94; A. Aspect, J. Dalibard, G. Roger, "Experimental test of Bell's inequalities using time-varying

analysers", *Phys. Rev. Letters* 49(1982), 1804-1807.
[29] For example, cf. F. Selleri, *Quantum paradoxes and physical reality* (Kluwer Academic Publishers, Dordrecht, 1990). It is interesting to note that Selleri's interpretation of Aspect's results is nearly the opposite of D'Espagnat [see Ref. 25]. Selleri says that the experiments to test Bell's inequalities were constructed to give results which infringe them. Selleri suggests that a real *experimentum crucis* has not yet been carried out. *He, but not the "orthodox" supporters, believes this*!
[30] P. Duhem, *La théorie physique* (Paris, 1914), ch. 6, sec. 12.
[31] Cf. K. Popper, The Logic of scientific discovery (Hutchinson & Co., London, 1959).

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