Problems in Objectizing

Bernard d'Espagnat

Laboratoire de Physique Théorique et Hautes Energies**,
Université de Paris-Sud, Bâtiment 210, 91405 Orsay Cedex, France

Abstract. When analysing differences between realists and (avowed or crypto-) idealists it is useful –in physics at least– to make a clearcut distinction between two different possible meanings of the word "Reality" and, more precisely, to call "Empirical Reality" the set of the phenomena and "Mind-Independent Reality" what is (at least by some) supposed to exist quite independently of human representations. This, in turn, leads to distinguishing between Strong (or Standard) Realism, a conception according to which the two just mentioned notions coincide, and Non-Standard Realism, a conception according to which they are different. Here the question is considered whether decoherence theory reconciles physics with Strong Realism or at least with the view that everything takes place *as if* Strong Realism were valid. It is shown that, in particular as far as locality is concerned, this is not the case. Varieties of Non-Standard Realism are then considered, with particular emphasis on Primas's theory and on the Veiled Reality approach.

In the course of time the views concerning the notion of "objects" –or "things"– evolved considerably as we know. In old –very old !– days physical objects were considered as existing per se, together with their attributes, essentially as they appear. Later, roughly at the times of Bacon, Galileo, Descartes and Newton, it was realized that this is presumably not the case in general ; but it still was held as obvious that, with the help of science and reason, human beings can gain a genuine knowledge of "the things as they really are", this knowledge being expressed by means of a few simple "clear and distinct" concepts, such as those of form, position, motion and divisibility by thought. Contrary to what might be expected, this conception was not appreciably altered by Kant's criticism for, although Kant considered objects by themselves as being out of reach, still he held that the just mentioned concepts are all right for describing the phenomena ; and he maintained that everything takes place *as if* the phenomena concerned such "per-se" objects. Let us call this the "assumption that the *objectivist language* is valid".

Still later –in Einstein's time, say– it was realized that this famous set of "clear and distinct" concepts –form, position and motion in Euclidean space, force etc.– is, after all, either inadequate or, at least, insufficient and has to be replaced or supplemented with concepts abstracted from mathematics. But most scientists kept to the view that with the help, whenever needed, of such new concepts we could describe the objects –or at least the events in some four-dimensional space– as they really are "in themselves". Or at any rate that

** Laboratoire associé au Centre National de la Recherche Scientifique - URA D0063

LPTHE Orsay 97/54
November 1997

everything takes place *as-if* such were actually the case. In other words they considered as valid a kind of generalized universal objectivist language, incorporating the said new concepts.

To such a view the advent of quantum mechanics stroke, of course, quite a serious blow. However, some –not all !– of the physicists interested in decoherence nowadays seem to consider that the development of this theory opens a possibility of restoring the view in question or at least its "hard core". Essentially : the view that we describe *some* objects as they really are : a view that we may call "macro-objectivism". In the first part of this lecture I shall look into this question and explain why I think that, on the whole, such a hope is unwarranted. In a second part I shall then dwell on what other possibilities, I think, remain of understanding the relationship between knowledge and reality.

1 Macro-Objectivism and Decoherence

Let us give a name to the set of all the phenomena, this word being taken in a Kantian sense. Let us call it : *Empirical Reality*. Then, the question I want to address to in this first part is as follows. "Can decoherence theory –possibly in conjunction with cosmological data– justify what I call "strong realism", that is, the view that there is no point in distinguishing Empirical Reality from Mind-Independent Reality (or that this distinction is purely philosophical, with no bearing whatsoever on our use of words and concepts) ?".

Decoherence is known to yield a satisfactory explanation of the *appearance* of a classical world and in particular, of locality of objects. Physicists such as Zeh, Joos and some others have shown this fact convincingly. But remember how they showed it. They showed it by referring to the interactions necessarily existing between a macroscopic object and its environment, by pointing out that the quantum correlations spread out very quickly over this whole environment and by proving that therefore no practically observable physical quantity exists, whose measurement would reveal the nonclassicality and/or nonlocality of ordinary macroscopic objects. As is –I think– well known, this does not lead to what I just called "strong realism". Concerning such basic matters, upholders of strong realism cannot consistently use the word "practical" in their reasoning since "practical" refers to human abilities and would therefore involve typically human structures in a description of "what is". What they use to do is therefore different. They refer to the fact that most environment quantities are genuinely unobservable –this, for example, is the case of the ones whose measurements would necessitate instruments larger than the size of the Universe !– and what they try to say is that this plus decoherence-theory *entails* –in a positive sense– the classicality and the locality of ordinary macroscopic objects. Now, the question I want to look at is : is this the case ? What I purpose to show is that, at least concerning locality, the answer is "no" : locality is not *entailed.* (Concerning classicality in general I also have reservations but of a more sketchy nature as you will see).

In order to make my point let me take up again the paradigmatic example, developed by Joos, of a dust grain of which we assume by convention that, at time zero, it starts scattering the particles composing its environment. Due to decoherence the reduced (partial trace) density matrix ρ_S describing an ensemble of such dust grains has, at time t, the form

$$\rho_S(x, x', t) = \rho_S(x, x', 0) \exp\left[-\Lambda t(x - x')^2\right] \tag{1}$$

Λ being the localization rate. In the case in which our ensemble of dust grains initially is a pure case, described by a Gaussian wave function

$$\Phi(x) = K^{1/2} \exp\left(-2Cx^2\right) \ . \tag{2}$$

Equation (1) then yields

$$\rho_S = K \exp\left\{-\left(Ay^2 + Cz^2\right)\right\} \tag{3}$$

with notations :

$$y = x - x' \quad ; \quad z = x + x' \quad ; \quad A = C + \Lambda t \tag{4}$$

so that, for Gaussian wave functions with large widths the conditions

$$C \ll A \quad ; \quad A \approx \Lambda t \tag{5}$$

are quickly met. In other words, ρ_S gets quickly squeezed along the first diagonal. As we know, this squeezing is partly counterbalanced by the natural growth of wave-packets, not taken into account in the above formulas, but Joos and Zeh showed that, when some kind of a steady state is reached, this squeezing –this increase of the shrinking coefficient A– still is present and important. It is readily shown that, due to it, no Young diaphragm with slit distance $d \gg A^{-1/2}$ can produce appreciable fringes.

Now, if, following Joos and Zeh, we diagonalize ρ_S we get

$$\rho_S = \sum_n p_n \ \phi_n(x) \ \phi_n^*(x') \tag{6}$$

where

$$p_n = \frac{2C^{1/2}}{A^{1/2} + C^{1/2}} \left(\frac{A^{1/2} - C^{1/2}}{A^{1/2} + C^{1/2}}\right)^n \tag{7}$$

and where the ϕ_n are the harmonic oscillator eigenfunctions

$$\phi_n(x) = N \ H_n\left[2(AC)^{1/2}x\right] \exp \cdot \left[-2(AC)^{1/2}x^2\right] \tag{8}$$

the H_n being the Hermite polynomials.

As you see, these $\phi_n(x)$ are all centered at the same value, $x = 0$, of x, which is not what we would expect if they were to describe subensembles of dust particles localized at different places distributed roughly according to a $|\Phi(x)|^2$

distribution law. Moreover, when C is much smaller than A the domain in which these ϕ_n have appreciable values is much larger than $A^{-1/2}$, so that any one ϕ_n taken alone could well generate fringes under conditions in which we know from $\rho_S(t)$ that the full ensemble does not. For these reasons, and following again Joos and Zeh, we may say that these ϕ_n are inappropriate to represent the localized particles we have in mind.

At first sight, this result is disappointing. It may look as if the theory were not capable of yielding localization, or, at least, not a sufficient one, and not of the expected kind. The oddity here, however, is not as great as it may seem. A point not explicitly made –to my knowledge– in the papers dealing with this subject is, at this stage, quite important. It is that, in fact, the theory allows for a stricter and more appropriate localization than the one the ϕ_n in Eq. (8) suggest. This is because of the well-known fact that a "true" density matrix (i.e. one that is not a projection operator) corresponds not to just one but to several –indeed an infinity of– different proper mixtures in the sense that it constitutes an adequate description of each one of them. Otherwise said : when it is not requested that the $|\phi_\alpha>$ be mutually orthogonal, any statistical operator ρ can be expressed in the form

$$\rho = \sum_{\alpha=1}^{\mu} |\phi_\alpha > p_\alpha < \phi_\alpha| \tag{9}$$

in an infinity of ways. A meaningful question then is : in the case of our squeezed ρ_S is there a choice of $|\phi_\alpha>$'s and associated weights p_α such that this ρ_S should be expressed in terms of them by means of a formula such as (9), all the $|\phi_\alpha>$'s being centered at different places and each of them being sufficiently peaked, that is, localized to within the "reasonable" length scale $A^{-1/2}$?

The answer is that at least one such choice exists. It is obtained by turning α into a continuous index variable X and setting (up to appropriate normalizing factors) $\phi(x, X, t)$ as given by

$$\phi(x, X, t) = \exp\left[-2B(x - X)^2\right] \tag{10}$$

B depending on t, and $p(X)$ as given by

$$p(X) = \exp\left(-DX^2\right) \tag{11}$$

with $D \ll B$, so that p has a much larger width than the ϕ's ; for expression (9) then reads

$$\rho_S(x, x', t) = \int_{dX} \exp\left[-2B(x - X)^2\right] \cdot \exp\left(-DX^2\right) \cdot \exp\left[-2B(x' - X)^2\right] \tag{12}$$

that is (again within some renormalizing factor)

$$\rho_S(x, x', t) \cong \exp\left\{-\left[B(x - x')^2 + \frac{BD}{4B + D}(x + x')^2\right]\right\} \ . \tag{13}$$

Expression (3) is then recovered by choosing B and D such that :

$$B = A \quad ; \quad C = \frac{BD}{4B + D} \ . \tag{14}$$

With our choice $D \ll A$ we then recover the "squeezing" condition $A \gg C$. Note that every $\phi(x, X, t)$ as given by (10) –where X serves as a continuous "index" as I said– is centered at one specific point X, so that these wave functions are, as expected, all centered at different places. Note also that none of them, taken separately, could generate fringes, which, again, is in accordance with our idea of quasi-local objects.

With this material at hand I can now make the point that I wanted to make. To this end, remember what the "strong realist" was trying to say. He was trying to say that, provided sufficiently many environment involving self-adjoint operators are void of physical significance, decoherence *entails* locality. If this means something it means, first that locality is a property of objects per se - not just an aspect of our predictive power - and second that an angel knowing quantum mechanics but with no notion of locality could *derive* dust grains locality from the theory ; same as a human being who never saw a stone being thrown could derive from gravitation theory the fact that, if thrown, a stone will follow a parabolic path. Well, we just saw that this hope cannot materialize. For this we only made use of the reduced density matrix, so that what we showed amounts to proving that even under the assumption most favorable to the realist –namely the extreme assumption that no environment-involving self-adjoint operator has "physical significance"– quantum mechanics and decoherence do not entail locality. It is true that decoherence solves the locality problem, but not in the sense of "strong realism". It solves it indeed in two senses. First it shows that when dealing with macroscopic objects we shall never observe such consequences of nonlocality as, for example, fringes. This is well-known. And second it shows –as we just saw– that, in spite of the wave-packets spreading phenomenon, we can, at any time, picture to ourselves an ensemble of macroscopic objects as being composed of individuals –or subensembles– having localized wave functions. Let me stress that the expression "we can" expresses both the extent and the limits of what has been done. We have not proved anything approaching "locality in itself". We have just shown that –granting environment unobservability as usual– the kind of local description of things that fits with our mental structure is one of those that are *compatible* with the general laws of physics. But do we believe that in an ensemble of dust grains governed by quantum mechanics this particular classical-like mixture that I exhibited happens to be the one that "really exists out there, full-stop" ? Certainly not. We should have no justification for such a belief. To some extent, what we got justifies a form of "as if" language : we see things *just as if* there was there a bunch of dust grains. But of course this is only a partial "as if", only concerning macro-objects. And we could say the description we produced is real only if we gave to the word "real" a meaning totally subordinate to men's aptitudes, which would be going very far... .

Let me end up this first part of my talk by saying a few words about decoherence and classicality. Does decoherence entail that, for example, after an ensemble of generalized –i.e. Schrödinger-cat-like– measurements have been performed each one of the pointers really lies in one definite graduation interval ? Some of the physicists with whom I discussed this issue had arguments that lead to the answer "yes" and seem convincing. But when you look at the matter from another angle you are not so convinced. And again, it may be a matter of what meaning we intuitively give to the word "real". Their main argument is one I hinted at already. It centers on the fact that many environment-involving Hermitian operators cannot correspond to observable quantities because of reasons having nothing to do with the quantum mechanical formalism proper : as, for example, the fact that the Universe is finite and that the complexity of the instruments needed for observing these quantities would exceed that of the whole Universe. I am not terribly happy with this type of argument and I found it interesting to try and pin up the reasons of this unhappiness of mine, suspecting that they had to do with my conception of what strong realism actually means. To be quite frank, I feel my argument is still but a half-baked one. That's why I shall be sketchy about it...

Rougly speaking, it rests on two "feet", a strict definition of realism and a continuity postulate. The first of these I borrow from the philosopher Dummett. According to him "realism" is "the belief that statements [...] possess an objective truth-value independently of our means of knowing it : they are true or false in virtue of a reality existing independently of us". This has a trivial but still quite important implication. It obviously implies that there must exist quite a large number of statements that have a definite truth value even though we are fully unable to check this value : for it would be quite an incredible coincidence if we –poor human things– happened to be able to experimentally check all of them. Are there some –within this set of the uncheckable ones– of which we may nevertheless be pretty sure they do have a truth value ? It it there that my principle –or "postulate"– comes in. It is a principle of continuation. I claim that, for instance, if a statement concerning pointers has a truth value when the environment is fairly simple, it still has one, it still is meaningful, when the environment is slightly more complex. To me this seems quite a natural assumption for increase in environment complexity is an imagined process that is essentially continuous, whereas transition from meaningful to meaningless would be a totally discontinuous jump. It seems incredible that adding one atom to a fairly complex environment could have such a dramatic consequence. Hence proceeding step by step, each time with very tiny steps, I feel I can justify the meaningfulness of statements concerning pointers, even, in the end, for arbitrarily complex environments. Anyhow, impossibility of measuring the sensitive environmental observables cannot be here a barrier since we are arguing within Dummettian realism, where statements have (or do not have) a truth value quite independently of us. To complete the argument it is now sufficient to consider an ensemble of generalized, Schrödinger-cat-like, measurement processes in which the environment is quite simple. In this case we know that the statement : "in the final state the pointers are in definite graduation intervals" has truth value "no" (since it has erroneous consequences concerning environment-involving observables that, in principle, we could measure). Then applying the continuation principle as just described leads to the conclusion that the same holds true when the environment is complex. In other words, the statement in question cannot be reconciled with strong, Dummetian realism.

In my eyes this argument has essentially the value that it clarifies the, initially somewhat obscure, nature of my misgivings concerning the viewpoint of the physicists I mentioned. But the subject is most delicate and complex and I would not be very surprized if the continuation principle met with serious objections. This is why I consider what I said before concerning locality as a more solid objection to the view that decoherence reconciles quantum mechanics with strong realism.

Anyhow, we have come to realize that there may be deep questions about the meanings of such words as "real", and "realism". This leads me to the second part of my talk, which is entitled

2 Beyond Macro-Objectivism and Standard Realism

Up to this point I argued within the realm of strong realism. However such a conception of realism –which, I think, may appropriately be called the "standard" one– is not, by far, the only standpoint that can be taken up in such matters. Many philosophers Dummett for instance –have objected to it on the ground that, in some respects, it verges on questionable metaphysics. To illustrate this point Dummett considers the case of a person's character. For the sake of this example he assumes that no one ever acts out of character and that no one's character ever change. And he argues : let us suppose that we ask of a particular man who lived in the past whether he was brave or not. If he ever performed a brave action, then he was brave. If he was ever in a situation of danger in which he behaved as a coward, then he was not brave. But suppose he was a quiet man and never found himself in such awkward situations. Is then the statement "he was brave" (or "he was not") meaningful ? Does it have a truth value ? Some people here would perhaps answer "yes", but I guess most of us would answer "no, not at all : in the case of this man such an assertion is simply meaningless". Which means they would consider that statements of such a kind do not really "possess a truth value independently of any conceivable means of knowing it" as "strong realism" would have it. They would –quite reasonably !– say that such statements, if true at all, can be true only in virtue of some event –or something– of which we could conceivably know. If this new definition of "truth" is extended from the realm of characterology to that of physics the result is what Dummett and others call the philosophy of "Anti-realism". It is clear that adopting anti-realism disposes of much of the objections (mine included) commonly made to the thesis that decoherence theory removes the Schrödinger-cat paradox.

The trouble of course is that anti-realism is closely connected with idealism in that both of them set human abilities in the forefront. Their implicit standpoint is that nothing than we can meaningfully speak of is more basic than human actions and knowledge, from which it follows that all of our concepts, definitions etc. must ultimately refer to the said actions and knowledge. Consequently idealists and anti-realists alike, when they use the word "reality" exclusively mean the set of the phenomena in the Kantian sense of the word, that is, what I called "Empirical Reality". There is however a difference between them, linked with the fact that Dummett's distinction between realism and anti-realism is based, not on the notion of existence or non-existence of things per se but on the notion of statements. Hence, in spite of the name "anti-realism" which I think concedes too much to idealism and should be changed, a Dummett-style anti-realist may be less reluctant than an idealist in accepting the notion of a Mind-Independent Reality, provided it is made clear that our ordinary statements about the truth or falsity of contingent facts do not bear on it and concern Empirical Reality exclusively. Following this path leads us to introduce a new variety of realism, that we may call non-standard realism, and which is characterized by the very fact that, in it, the two notions of Mind-Independent Reality and Empirical Reality are viewed as being (i) significant and (ii) *distinct* from one another

There are of course several possible versions of such non-standard realism. One of them consists in asserting that Mind-Independent Reality is utterly unknowable. At the other end of the spectrum we find the so-called "ontologically interpretable models", of which the Bohm model is probably the most interesting. It is certainly the oldest since it was discovered by Louis de Broglie as early as 1927. It was called "the Bohm model" after the name of the first American who took an interest in it... (please take this remark with a big grain of salt ! It is unquestionable that Bohm rediscovered the model and much developed it so that, when all is said, the name "Bohm model" does have rationality). In fact the starting point of this model was the idea that also Mind-Independent Reality should be knowable and moreover should be structured more or less according to the same patterns as classical reality, that is, made up of particles and fields. But of course what this idea finally led to was a nonlocal theory : as we now know, this was unavoidable because of the Bell theorem. And this casts a kind of a doubt on the pertinacy of the very starting-point of the theory. For, as Bitbol stressed, why start up with classical, that is, essentially local concepts if it is to give up locality in the end result ? By the way, the said nonlocality is what made me put the Bohm model within the category of nonstandard realist ones, for it implies that, in Bohm's language, the explicit order does not coincide with the implicit one : which, in my language, means that Empirical Reality does not coincide with Independent Reality.

Still another conception of non-standard realism –the one, in fact, I favor– is a midway one. It consists in considering that such things as the great general laws of physics provide us with some glimpses on Mind-Independent Reality, although these glimpses are presumably partial and may well be highly distorted. The most ambitious model along these lines is, I believe, that of Primas. I think you all know it, so let me just very briefly tell you of my own understanding of it. I see it as based on a guess : the guess that Mind-Independent Reality has the structure of standard quantum mechanics with the Born rule removed. Removing the Born rule implies, when all is said, that the theory cannot be tested experimentally. But it also implies that (i) it involves no statistics and (ii) contrary to conventional quantum mechanics it does not partake of the nature of a mere set of recipes : it can be seen as descriptive of great structures. Note morover that the thus described Mind-Independent Reality is fully holistic. This is due to the universal existence of cross terms and the like, called Einstein-Podolsky-Rosen (EPR) correlations in Primas's terminology. Consequently objects, events, contingent facts etc. are not elements of this Mind-Independent Reality. All these "phenomena" are just aspects of this reality as seen by us.

As many of you have probably noticed, I somewhat simplified the description of this stage of Primas's views. In fact Primas combines this removal of the Born rule with a generalization of the Hilbert space formalism to what he calls an algebraic formulation. The resulting formalism he calls "endophysics". At this stage we might of course be tempted to say that such an untestable endophysics is mere fancy. But the beautiful point in Primas's work is still to come. It is that from endophysics we may recover the phenomena, we may recover molecules, chemistry, thermodynamics etc. under the condition that we "make abstraction" from this or that EPR correlations set. This shows in quite a vivid way that it is we who carve out Empirical Reality from the holistic Mind-Independent Reality, same as the sculptor carves out the statue from a marble block. But it shows even more. Primas shows that we get one or the other of mutually exclusive scientific descriptions of Empirical Reality according to the EPR correlations we choose to discard. For example, one choice leads to molecules while another one leads to temperature. So there is no point in trying to explain thermodynamics by means of a molecular structure or the reverse. Neither one of these two aspects of Empirical Reality is more fundamental than the other. This is a point that Primas repeatedly stressed and I think it is a very nice one. Another point (although of much more restricted significance) that I would like to make along the same lines is that there is some similarity between Primas's idea that we carve out Empirical Reality from Mind-Independent Reality and what I said a moment ago concerning locality. In both cases the result is not "inferred from endophysics full stop", as classical physicists would have expected. But neither is it postulated - in a Kantian style - as a primitive element of whatever we may call "Reality". What is inferred is that the kind of descriptions our mental features lead us to are compatible with the structures that we have grounds to think are those of Mind-Independent Reality.

As I said, in my view Primas conception is just a guess. To believe that we have thus reached –in an oblique, indirect way !– the very structures of Being-in-Itself is indeed a most daring guess. But it is a beautiful one and anyhow Primas's grand view may be seen as an explicit –even, in a way, quantitative– example of a much more general and vague conception which, I must say, I always favored. This is the conception that Reality, first, does not boil down to human knowledge, as idealists would have it, and, second, is not "made up" of contingent facts or the like. In a way, my favorite expression "Veiled Reality", is meant to convey this idea. In particular, it is meant to convey the view that, although we cannot know Mind-Independent Reality, still we get, through physics, not fully deceitful glimpses of it. I feel Primas's optimistic guess somehow strengthens my position in this matter.

References

d'Espagnat, B. (1995) : *Veiled Reality* (Addison-Wesley Publ. Co., Reading, Mass, USA)

Primas, H. (1981) : *Chemistry, Quantum Mechanics and Reductionism* (Springer, Heidelberg)

Primas, H. (1992, 1994) : Symposia on the Foundations of Modern Physics (Finland), (World Scientific, Singapore ; Editions Frontière, Gif-sur-Yvette, France)