Brit. J. Phil. Sci. 40 (1989), 29–37 *Printed in Great Britain*

Primary Qualities are Secondary Qualities Too

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1 INTRODUCTION: REALISM AND QUANTUM MECHANICS

Quantum theory appears to be a gift from the gods for philosophers of an anti-realist persuasion. It is a well established and very successful theory which appears to defy a realistic interpretation. I shall argue in this paper that a realistic interpretation of quantum mechanics *is* possible, though not without some change in our conception of the nature of the real. I take it to be very important that this is possible; for, ultimately, realism is the only satisfactory view. I shall not argue this here. I say it merely by way of putting my cards on the table.

2 THE COLLAPSE OF THE WAVE PACKET

Let us start with the problems of giving quantum mechanics a realistic interpretation. These are all aspects of the one fundamental problem of the collapse of the wave packet; so let me describe this.

Let us suppose that we have some system, S, which can be in a range of macro-states, X. We might think of S as an electron and a member of X as the state of occupying a certain point in Euclidean 3-space. (More picturesquely, one might think of S as Schroedinger's cat, and X as the pair <dead, alive>.) It will be useful to have a name for the sorts of things that can be in X. For reasons that will become clearer later, I will call them *Newtonian* properties. The situation S is in at any time is given by a *state function*, ψ. Mathematically speaking, ψ can be conceived of in several ways; but a standard way of thinking of it is as a vector in a certain vector space over the complex numbers. The state function, although in some sense specifying what is there, does not tell us what an observer will 'see' if they look at the system, that is, which Newtonian state S will appear to be in if this is experimentally determined. For example, it does not determine where the electron will appear if someone measures its location. At best, ψ determines, via certain vector operations, the probability of S being observed to be in a particular state in X.[1] Yet when S is observed, it is always found to be in exactly one state in X.

One should not, incidentally, read too much into the word 'observer'. Although it is sometimes suggested that 'the observer' in quantum mechanics must be conscious, this is, at least as far as I can see, quite unnecessary; the observer might be a person, a camera, a screen, or any other interacting system. Now, to return to the main point, according to the orthodox, Copenhagen, interpretation of quantum mechanics, S is in no determinate Newtonian state before an observation, but is precipitated into one by it. This is the so called collapse of the wave packet. But to a realist it seems absurd to suppose that the mere observation of the system somehow forces it into the state it is observed to be in. The supposition that the system has the property of being in that state only by being observed is, indeed, a form of idealism. To be sure, the observation, by causally interacting with S will force it into a new state, ψ', *subsequently*; but if S is observed to be in a certain state at a certain time then, presumably, the state is determinate prior to observation.

To bring this home is the point of the famous Einstein/Podolsky/Rosen thought experiment. One way of looking at this is as follows: A pair of particles, a and b, is produced in a singlet state. This means that they have correlated spins (or some other property). When the particles are a long way apart we determine the spin of a, and hence, the spin of b. Now at what point did b obtain this spin? Not when *it* was observed. (We can even ensure that no observation is made to determine b's spin by measuring a complementary property.) Nor can it be when a's spin was measured—because a and b are a long way apart when this happens. It must, therefore, have had it all along.

Thus, to a realist, it will appear that the state description, ψ, is a seriously incomplete description. We have therefore seen the development of 'hidden variable' theories in quantum mechanics, which try to eliminate the incompleteness by the addition of another parameter. These have not, perhaps, been notably successful; but at least until relatively recently it was possible to hope that something like this could be made to work. This is now a very dubious hope. By one of the major ironies of the subject, the Einstein/Podolsky/Rosen thought experiment was transformed into an actually

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[1] Specifically, the probability of S being observed to be in state x is $q^* \cdot q$, where q is the coefficient of the eigenvector corresponding to x in the expansion of ψ along the basis provided by the class of all such eigenvectors.

performable experiment by the ingenious Dr. Bell; and the experimental verdict has gone against realism. In Bell's experiment we take large number of pairs of, *e.g.*, electrons in a singlet state, and measure complementary properties of each member of the pair. When we try to explain the observed results on the realist assumption that the measured Newtonian property—spin—is intrinsic, and assume locality—that there is no communication between the particles after they separate—we get the wrong result. Rather, the result is as quantum mechanics predicts.[2]

Hence, it would seem that the system, S, is not determinately in any Newtonian state before it is observed to be so (unless locality is violated—a straw at which even a drowning man would think twice before clutching). 'Confusion to my enemies' says the idealist.

3 PRIMARY AND SECONDARY QUALITIES

It is clear that the 20th century has seen profound changes in physics. Part of the problem in getting to grips with their import is in obtaining a suitable sense of perspective for something that close. I will therefore leave the subject of quantum mechanics for a while and discuss briefly the only period in physics comparable in the profundity of its changes—the scientific revolution of the 17th century. It seems to me that there are some important lessons to be learnt from this. In particular, I want to focus on the change in the conception of matter that occurred at this time. As a result of the work of Galileo, Descartes and others, the mechanistic conception of matter was formed. Matter is characterized primarily by its extension and its locatability in space and time. These (and a few other) Newtonian properties are its primary properties. It would have them even if there were no perceivers of matter. By contrast, a number of the properties of matter, that had been thought of as on a par with, or even as more important than, these before, became thought of as secondary. Principally, the colour, smell etc. of matter were not intrinsic to it, but were in some way relational, relating the matter observed and the observer. If there were no observers, then matter would not be coloured in the same way that it is extended.

The distinction between primary and secondary qualities was laid out explicitly by Boyle and Locke. I shall not discuss it and its rationale at any length here. I note only that, first, the secondary properties of an object arise because of the interaction between the object and an observer—indeed, it is just their observer-relativity which marks them out; and secondly, this distinction, however, one fills in the exact details, is now well established: the colour something appears *is* dependent on the state of the sense organs of the perceiver, the context of perception etc. (Though, one should note, this does

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[2] For an excellent description of this, together with a case for idealism on the basis of it, see Mermin [1981].

not make secondary qualities subjective, at least in one sense: similar observers in similar situations still have the same perceptions.)

Of course, matter can have an intrinsic dispositional property of producing *that* kind of perception in *that* kind of observer; and this is sometimes called a secondary property too. However, I shall use the term 'secondary property' solely as referring to the appearance. This disposition is therefore not a secondary property, but its (partial) cause. How one is to understand these dispositional properties is another question. Historically, it was answered only with the appearance of the 19th century atomic theory of matter and wave theory of light. With the help of these, it could be shown that the dispositions were really aggregate primary properties of the micro-structure of matter. It then became clear that to say, *e.g.*, that fundamental matter, an atom, is coloured, is not just false, but is a category mistake. Thus did these theories bring to fruition the mechanistic conception of matter, a conception that changed profoundly our understanding of matter, its properties, and their relationship to the observer.

4 WHAT'S THE MATTER NOW?

With this historical situation fresh in our thoughts, let us now return to that in quantum mechanics; for there is a strong analogy between the two situations.[3]

The scientific revolution produced a novel conception of matter according to which matter was radically different from the way in which it had been conceived of previously. Much of how it had been conceived of before was consigned to the realm of appearances. It is perhaps easy to overlook the strangeness of the idea of matter that is essentially colourless, textureless, etc., to 17th century sensibilities. The fact that many of the old paradigm properties of matter became perceiver-dependent made it tempting to think that there is nothing to matter itself over and above what is perceived. Thus, the scientific revolution could seem to entail idealism. Indeed, Berkeley and Hume were tempted to the point of succumbing. However, once one becomes clear that it is a new notion of matter which is at issue, with different essential properties, it becomes clear that there is nothing in the new *science* that requires idealism; quite the contrary: matter is as real as it ever was.

In a similar way, it seems to me, the situation in quantum mechanics should be seen as occasioning a revision of our conception of matter (that is, of physical reality). The fact that the conception of matter produced by the 17th century scientific revolution took several hundred years to come to fruition, should remind us that we need to exercise extreme caution in saying what

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[3] This analogy was first noted, as far as I am aware, by Sava Petrov. See, *e.g.*, his [1985]. The conclusions he draws from this analogy are, however, somewhat different from those I shall draw. I am grateful to him for his comments on an earlier draft of this paper.

form the new conception of matter will finally take; but the outlines, at least, seem fairly clear. Reality, whatever that is, is described completely, and without residue, by state functions such as ψ. Thus, these functions are to be interpreted realistically, not instrumentally. Reality, or matter, then, is the physical realization of a certain kind of vector. (Just as a force is the physical realization of another kind of vector.) Let us call these realizations *ψ states*. The 'shape' of a state (in particular, the coefficients of its eigenstate expansions) is an intrinsic property of that state. Such properties are observer-independent, and are analogous to the primary properties of the mechanistic conception.

A Newtonian property such as having a certain spin (or, perhaps better now, appearing to have a certain spin) is not an intrinsic property according to this conception, but is observer-dependent. Such properties result from an observation acting on the ψ state, just as the mathematics, where the operator corresponding to the observation acts on the ψ function, has it. Thus, Newtonian properties are analogous to the secondary properties of the mechanistic conception.

The change in conception is a radical one; but that is, after all, what scientific revolutions are all about. However, it should be clear that the new scientific situation no more requires the rejection of realism than did the 17th century scientific revolution. ψ states exist with a determinate nature quite independently of any cognition. One can draw the idealist conclusion only if one clings to the old conception of matter, taking the paradigm properties of the old conception to be the essential properties of matter itself. Nothing in the science requires us to do this.

5 REALISM AND NON-LOCALITY

Let me spell out some of the consequences of this view, particularly those concerning non-locality. Bell's experiment leaves a traditional realist little option but to accept some kind of non-locality. However, this should not be particularly surprising. After all, essentially the same conclusion can be drawn from a much more traditional experiment in quantum mechanics: the two slit experiment. I will first discuss this; then return to Bell's experiment.

In the two slit-experiment a light is shone through parallel slits in a mask, and the resulting light falls on a screen. If one tries to understand the result in particular terms, it would appear that the light pattern on the screen *ought* to be the sum of the two patterns obtained from each slit independently; but it is not. The situation becomes extreme when the intensity of the light is reduced until only a single photon goes through the mask at any time. The result then ought to be either the result of the particle going through one slit, or the result of it going through the other; but in fact, it is neither. The particle 'knows' that one slit is open, even though it goes through the other. For the idealist of the Copenhagen variety, this poses no problems: since the particle is not observed to go through either slit, it in fact goes through neither. So the question of how it 'knows' that one slit is open when it goes through the other does not arise. To the traditional realist this is absurd; yet the only alternative seems to be that the open slit which the particle does not go through exerts some influence on it. Hence they are forced into accepting non-locality, or, to give it its traditional name, action-at-a-distance.

Realists of the kind I have been describing are not forced into this situation, however. For they can agree with the idealist that the 'particle' has no position independently of being observed at the screen. Indeed, there is no particle in reality, just a ψ state determined by the light-source and mask. To suppose that one of the slits has an effect on a particle located elsewhere, is precisely to suppose that there is a particle in reality, and that its position is an intrinsic (non-observer-dependent) property. To invoke action-at-a-distance is, therefore, to completely misunderstand the situation. The projection of these 'secondary' qualities onto reality is just as mistaken as Protagoras' projection of contradictory properties onto reality merely because things are perceived in contradictory ways by different observers.[4] As should be clear, however, the agreement with the idealist about the above does not entail agreement about idealism, any more than rejecting Protagoras' projection commits one to the view that all properties are secondary properties.

The same point is to be made about the Bell experiment. To suppose that the observation of one particle affects the other at a distance is to presuppose the existence of particles with intrinsic Newtonian properties. But there are, in reality, no two particles with intrinsic positions. The real situation is described, quite literally, by a certain ψ function. There is but a *single* state, and spin-at-point-A and spin-at-point-B are two of its observer-relative (Newtonian) properties. Thus, the Bell experiment may force us to give up the intrinsic nature of Newtonian properties, but it does not force us to give up realism.

It remains true that there is a certain holism involved in quantum mechanics. For the result of an observation at point A, which depends, in part, on the observing set up there, can certainly have implications for the result of another observation at point B, a long way away. But that's just what quantum mechanics tells us that reality is like. It may be surprising, but it does not reflect ill on the realism I have been suggesting. In particular, we are not forced into the embarrassing position of speculating about the spurious mechanism involved, or, what this comes to, into non-local hidden variable theories.

6 AN OBJECTION

Before I conclude, let me answer an objection to this account.[5] Take some state, ψ, and make the same observation on it twice. Suppose, for example, we

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[4] See, *e.g.*, p. 20f of Kerford [1949].

[5] For which I am indebted to an anonymous referee.

measure spin. As long as nothing happens between observations, we will get the same answer both times (as quantum theory predicts). Now, if the spin is not an intrinsic property of the particle this 'coincidence' would not occur in general. Hence spin must be intrinsic. The major premise of this argument concerning spin is, however, false. Even though the spin is not an intrinsic property of the particle, none the less, the observed spin in a product of the ψ state and the measuring device, and if these are the same in both cases the result is, naturally, the same. After all, one observer (or two observers identical in the relevant respects) who makes two observations of the same (macroscopic) object under the same conditions will see it as having the same colour both times.

It may be replied that the state of the particle is *not* the same on the two occasions. The first observation will result in the state changing to a (different) eigenstate of the observation operator, ψ'. This may be so, but misses the point. Even in the case of the colour observation, the conditions under which any two observations are made are never identical; they need only be the same in the relevant respects (light conditions etc.). And ψ and ψ' *are* the same in the relevant respects. What are the relevant respects? To answer this we can only be guided by the theory. This tells us that to some extent it may be a matter of chance what we observe on the first observation; but second and subsequent observations, acting on an eigenstate, must produce the same result. The theory therefore *tells* us that the states are relevantly identical.

The objection is, in fact, doomed to failure for very general reasons: it is impossible to refute the interpretation of the formalism I have suggested on the grounds that it does not explain something, if that very thing is predicted by the formalism; for my suggestion is exactly to take the formalism *seriously.* It provides the one and only account of what is really happening.

7 THE HIERARCHY OF MATTER

It is tempting—a temptation to which I succumbed in giving this paper its title—to sum up the line of thought I have been suggesting, by saying that primary properties (such as spatial location) are really secondary properties; and there is some justice in this aphorism. However, it is also quite misleading: there are very real dissimilarities between secondary properties, as traditionally conceived of, and Newtonian states in quantum mechanics. For a start, although both kinds of property are (objectively) relative to an observer, for secondary properties the observer must be conscious; whereas for Newtonian properties the observer need not, as I have already noted. Secondly, traditional secondary properties are determinate functions of state-plus-observer, whilst Newtonian properties are non-determinate, probabilistic properties of state-plus-observer.

Thirdly, and most importantly, the two kinds of property are observer-relative at different 'levels' of reality. Matter may be thought of as hierarchically organized.[6] Its behaviour at each level may be explained in terms of the structure of the level below. Thus, the behaviour of macroscopic bodies and their properties is explained in terms of the (primary) properties of its microscopic (atomic) parts. The behaviour of these and their properties is, in turn, explained in terms of their quantum states and properties. Maybe the hierarchy goes further, though if it does, we haven't got there yet.[7] Now traditional secondary properties are properties of matter at the macroscopic level; their perception in an observer is caused (in part) by a dispositional property to be understood in terms of structure at the microscopic level. Newtonian properties, on the other hand, are properties at the microscopic level (and so, derivatively, at the macroscopic level); their registering with an observer is caused (in part) by dispositional properties (or propensities) to be understood in terms of structure at the quantum level. This may be depicted in the form of a table:

Level	*Characteristic property*	*Produced by*	*Dispositions are*
Macro	secondary	macroscopic disposition plus observer	aggregate properties of primary states
Micro	primary (Newtonian)	microscopic disposition plus observer	vector properties of quantum states
Quantum	quantum	?	?

If there is a level below the quantum level then presumably there is an entry in the second, and perhaps the third, column of the third row also. At any rate, the table illustrates how science reveals more and more fundamental structures of matter. And properties taken to be absolute at one level may be found to be observer-relative at the next.

8 CONCLUSION

It is possible to see a good deal more of 20th century physics in this light. Quantum theory shows spatio-temporal locations to be observer-relative. But,

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[6] See, *e.g.*, ch 3, section 3 of Bhasker [1975].

[7] Note that the levels are not defined in terms of orders of physical magnitude. Though going down a level may involve moving to smaller entities, the hierarchy is defined in terms of causal dependence. Note also that the discovery of the level below may well reshape our conception of the level above.

in a sense, the Special Theory of Relativity shows space and time themselves (or, at least, spatial and temporal separations) to be 'secondary properties': frame-relative derivatives of absolute space/time (or proper time). However, realism was the topic of this paper; and relativity theory has never been considered to be a challenge to this in the same way quantum mechanics is. Thus, for the present at least, this matter need exist only in the mind of the reader.

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