International Journal of Theoretical Physics, Vol. 34, No. 8, 1995

Why Modal Interpretations of Quantum Mechanics Must Abandon Classical Reasoning About Physical Properties

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Received March 28, 1995

Modal interpretations of quantum mechanics propose to solve the measurement problem by rejecting the orthodox view that in entangled states of a system which are nontrivial superpositions of an observable's eigenstates, it is meaningless to speak of that observable as having a value or corresponding to a property of the system. Though denying this is reminiscent of how hidden-variable interpreters have challenged orthodox views about superposition, modal interpreters also argue that their proposals avoid any of the objectionable features of physical properties that beset hidden-variable interpretations, like contextualism and nonlocality. Even so, I shall prove that modal interpreters of quantum mechanics are still committed to giving up at least one of the following three conditions characteristic of classical reasoning about physical properties: (1) Properties certain to be found on measuring a system should be counted as intrinsic properties of the system. (2) If two propositions stating the possession of two intrinsic properties by the system are regarded as meaningful, then their conjunction should also correspond to a meaningful proposition about the system possessing a certain intrinsic property; and similarly for disjunction and negation. (3) The intrinsic properties of a composite system should at least include (though need not be exhausted by) the intrinsic properties of its parts. Conditions 1–3 are by no means undeniable. But the onus seems to be on modal interpreters to tell us why rejecting one of these is preferable to an ontology of properties incorporating contextualism and nonlocality.

1. INTRODUCTION: THE INTERPRETATION OF QUANTUM MECHANICS AS A PROBLEM ABOUT PHYSICAL PROPERTIES

The main task faced by interpreters of quantum mechanics seems to be that of extracting a coherent and physically sensible story from the theory about physical properties.

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0020-7748/95/0800-1303$07.50/0

The first stumbling block to this enterprise comes from Heisenberg's relations. Are these merely *uncertainty* relations limiting our knowledge of the simultaneous values of incompatible observables? Or are they *indeterminacy* relations symptomatic of a deeper breakdown of classical physical concepts (like position and momentum) at the level of an individual system?

If we suppose we *are* dealing with an instance of conceptual breakdown here, as orthodox interpretations of the theory would have it, this breakdown has some curious, indeed nearly paradoxical, implications. As the infamous debate between Einstein–Podolsky–Rosen and Bohr brought out, one would have to say that which concept is applicable to a given system (e.g., position versus momentum) must depend, not just on which measurement one subjects that system to, but *also* on which measurements one subjects other faraway systems to, which, if not outright action at a distance, is at the very least 'spooky' (to borrow Einstein's characterization). Moreover, as Schrödinger poignantly emphasized, once one imposes limitations on the simultaneous applicability of basic physical concepts at the microlevel, one has no natural way to prevent these limitations from coming into force at the macrolevel and stopping us from asserting seemingly reasonable things, for example that a cat is definitely either alive or dead. No natural way, that is, other than stipulating by fiat that macroscopic objects like cats are to be classically described, and perhaps introducing a collapse postulate into the theory to secure the possibility of such description.

So the obvious thing to do to avoid all that would seem to be to just deny conceptual breakdown, go the way of the hidden-variable theorist, and reassert determinacy and the simultaneous applicability of "incompatible" physical concepts despite our inability to simultaneously measure them. At least that way Schrödinger's cat would no longer haunt us! But we learn from the theorems of Kochen–Specker and Bell that this is still no easy route back to a reasonable and physically intuitive ontology of the properties of quantum systems. For not only must we now admit that the value of an observable A must sometimes be found to be different when measured along with B as opposed to C (where $[A, B] = 0$, $[A, C] = 0$, but $[B, C] \neq 0$), but that this must be so even if the observables B and C pertain to a system spacelike separated from the system that A pertains to! In short, not only must we in some sense create values for observables like A when we measure them, on a hidden-variable view, but orthodoxy's 'spooky' action at a distance starts to look more and more, in this new incarnation, like the real thing!

The difficulties posed by the dilemma of choosing between the orthodox and hidden-variable conceptions of quantum properties are thus very acute. But there is another way of looking at the whole dilemma which promises a relatively painless resolution of it. The resolution is offered by so-called 'modal' interpretations of quantum mechanics, which have a distinguished list of advocates: Bub (1994), Dieks (1993), Healey (1989), Kochen (1985), and van Fraassen (1991).[2]

All these interpretations are, in a way, hybrids of the orthodox and hidden-variable viewpoints. Like orthodoxy, they impose restrictions on the properties one may simultaneously ascribe to a quantum system at any given time. But these restrictions are not so stringent that one is prevented from ascribing a definite property of life or death to Schrödinger's cat when it gets entangled with some potentially cat-killing device, so in that sense, these interpretations are like the hidden-variable point of view. However, precisely because modal interpretations do not go all the way toward hidden-variables and claim that *all* observables of a system correspond to intrinsic properties it possesses, one of their 'selling points' is supposed to be that they avoid any objectionable contextualism or nonlocality of the kind required for hidden-variable theories by the theorems of Kochen–Specker and Bell. So their interpretive package is supposed to secure a sensible, if restricted, notion of the properties of quantum systems, without all the physically implausible baggage of hidden-variable theories.

Despite this, the aim here will be to emphasize that these modal interpretations do, and more importantly *must*, involve some significant deviation from the usual 'classical' notion of what it means for an intrinsic property to be possessed by a system. So these interpretations are certainly not exempt from the task of defending their own conception of properties against those of orthodoxy and hidden-variable theories.

2. MODAL INTERPRETATIONS AND CLASSICAL REASONING ABOUT PHYSICAL PROPERTIES

Recall once again that the aspect of the problem of properties emphasized by Schrödinger was what to make of entangled superpositions of states like the following (where I have used the usual ket and tensor product notation, and am letting $w_1 + w_2 = 1$, $0 < w_1 \neq w_2 < 1$):

$$|\psi\rangle = \sqrt{w_1}\,|\text{Decay after time } t\rangle_{\text{Atom}} \otimes |\text{Dead}\rangle_{\text{Cat}} + \sqrt{w_2}\,|\text{No decay after time } t\rangle_{\text{Atom}} \otimes |\text{Alive}\rangle_{\text{Cat}}$$

If our attitude is an orthodox one, so superpositions like this indicate that the terms in them must refer to observables which lack definite values, then we are put into the uncomfortable position of denying objective reality to much cherished properties, like life versus death, of everyday macroscopic objects, like cats.

[2] I have only taken the trouble to mention the most significant recent publications of these authors.

On the other hand, modal interpreters, though not in the business of allowing *all* observables of a system to be simultaneously ascribed values (which would automatically force both contextualism and nonlocality), *do* grant the 'life observable' of the cat in the above entangled state the status of being a definite property of the cat *despite* that entanglement. Clearly, then, modal interpretations are operating under a different, nonorthodox criterion for what it means to possess an intrinsic property.

We need not be detained by outlining the details of that criterion, or should I say those criteria: for the proposed new criteria for property attributions differ, sometimes in subtle ways, from one modal interpreter to another.[3] All we shall need to focus on is the two central claims to which all modal interpreters subscribe:

MI_1: *Schrödinger's cat is definitely alive or dead despite its entanglement in* $|\psi\rangle$.

MI_2: *At any given time, only a proper subset of all possible properties of a given system correspond to the definite ("intrinsic") properties it actually possesses.*

MI_1 distinguishes these interpretations from orthodoxy, and MI_2 from hidden-variables.

Since the projection operators of any system S's Hilbert space correspond to all the different possible propositions that assert S possesses some *particular* property, it is useful to reformulate the above claims succinctly as follows. When the composite system of which S is a component occupies the pure quantum state $|\phi\rangle$, let $\mathrm{Def}_{|\phi\rangle}(S)$ denote the set of particular intrinsic properties system S possesses in that state, where this set is represented, in general, only by a *subset* of the set of all the projection operators, call it $\{P(S)\}$, defined on the Hilbert space for S. For projection operators with one-dimensional range generated by a vector $|\phi\rangle$, we will use the standard notation $P_{|\phi\rangle}$. In the case of Schrödinger's cat, modal interpreters have then committed themselves to asserting the following[4]:

MI_1: $\{P_{|\mathrm{Alive}\rangle_{\mathrm{Cat}}}, P_{|\mathrm{Dead}\rangle_{\mathrm{Cat}}}\} \subseteq \mathrm{Def}_{|\psi\rangle}(\mathrm{Cat})$.
MI_2: $\mathrm{Def}_{|\psi\rangle}(\mathrm{Atom} + \mathrm{Cat}) \subset \{P(\mathrm{Atom} + \mathrm{Cat})\}$.

By deviating from orthodox and hidden-variable property ascription in this way, I will show that modal interpretations have, in a sense, 'painted

[3] It is precisely because I want to avoid one of these differences that I have chosen $w_1 \neq w_2$ in state $|\psi\rangle$; for in the unlikely event that $w_1 = w_2$ (exactly), the criteria of property attribution proposed by Dieks and Healey only license ascribing the trivial observables 0 and I definite values for the Cat system (so they will only endorse MI_1 when $w_1 \neq w_2$).

[4] They are also committed to the analogs of MI_2 for the Atom and Cat systems separately, but these will not figure in the discussion to follow.

themselves into a corner' by having to give up at least one of three other features of classical property ascription which are independent of the requirements of noncontextualism and locality.

I shall formulate each of these three features of classical property ascription I have in mind as a condition on the set $\text{Def}_{|\psi\rangle}(\text{Atom} + \text{Cat})$ that we might *at least classically* expect to be satisfied. As it happens, all the different modal interpretations in the literature violate one or more of these conditions, as I will shortly point out. The fact that they *must* do so, simply as a consequence of affirming MI_1 and MI_2 above, will be proved in the next section. Let me emphasize, though, that I am not claiming these three conditions are *a priori* or in some way undeniable, but simply that denying them could well be seen as no worse than endorsing things like contextualism and nonlocality.

First, properties which are certain to be found on measuring a system should surely be regarded as being truly possessed by the system. If we can always correctly predict with certainty that every time I look at the moon I will find it up there in the sky, then it is (classically!) no grave mistake to make the inference that it really is there even when, on some occasion, I choose not to look. In fact, the real presence of the moon up there is the best explanation for why it is true that I am bound to see it *if* I look! So we at least expect that the following will hold true of the set $\text{Def}_{|\psi\rangle}(\text{Atom} + \text{Cat})$:

$$\mathbf{CP_1}\text{: } \text{Prob}_{|\psi\rangle}(P = 1) = \text{Tr}(PP_{|\psi\rangle}) = 1 \Rightarrow P \in \text{Def}_{|\psi\rangle}(\text{Atom} + \text{Cat}).$$

Note that this kind of inference to the presence of a property would be utterly spurious if the prediction with certainty about finding that property were somehow achieved at the expense of disturbing the system. That, of course, was the crucial dispute between Einstein–Podolsky–Rosen and Bohr! If my looking up in the sky happens to be what *makes* the moon be where it is, then I undercut any grounds I might have for saying it is up in the sky when I am not looking. However, *unlike* in the EPR–Bohr debate, we are not here considering an instance of prediction with certainty which is gained at the expense of conditionalizing on a measurement result obtained on another system entangled with the system under consideration. We may suppose the Atom + Cat system under consideration, though itself entangled, is not entangled with any aspect of its environment, so that all CP_1 says is we should take those projections which have the Atom + Cat's state $|\psi\rangle$ as an eigenstate (with eigenvalue 1) to represent possessed properties. In that case, it is well known that a measurement of any such projection (albeit a complicated measurement to practically perform on a macroscopic system) will not disturb the state $|\psi\rangle$.

Second, suppose we have two propositions that state the possession of two different intrinsic properties of a system, like "This marble is red" and

"This marble is opaque." If we regard these propositions as meaningful, let us say true, of the marble, so the corresponding properties actually *are* possessed by it, then (again, classically!) we are predisposed to regard the proposition "This marble is red **and** opaque" as a meaningful ascription of a true (conjunctive) property to the marble. Similarly, of course, for "This marble is red **or** opaque" and "This marble is **not** black." Thus intrinsic properties of a system should be amenable to logical combination in these ways to produce new propositions that meaningfully attribute intrinsic properties to the system. What this means is that the set of propositions ascribing intrinsic properties should be closed under conjunction, disjunction, and negation. Since the only natural analogs of these operations we have for projection operators are subspace intersection ($\cap$), span ($\oplus$), and orthogonality ($\perp$), it is natural to require the following of the set $\text{Def}_{|\psi\rangle}$(Atom + Cat):

CP₂: $\{P, P'\} \subseteq \text{Def}_{|\psi\rangle}(\text{Atom} + \text{Cat}) \Rightarrow \{P^{\perp}, P \cap P', P \oplus P'\} \subseteq \text{Def}_{|\psi\rangle}(\text{Atom} + \text{Cat})$.

Notice that I have not required P and P' to be compatible, so CP_2 demands that $\text{Def}_{|\psi\rangle}$(Atom + Cat) form an ortholattice under $\cap$, $\oplus$, and $\perp$. I am well aware that there is a perfectly respectable strain in quantum logic which requires only closure of property-ascribing propositions under these ortholattice operations *restricted to compatible projections*, thus only requires that such propositions form a partial Boolean algebra. But if it turns out that modal interpretations have to go to such lengths to secure a consistent conception of properties in quantum mechanics, then that would be very interesting indeed. Certainly hidden-variable interpretations which ascribe all observables definite values automatically satisfy CP_2, and so have no need to revise classical logic to account for its violation. And even orthodox interpreters would not deny CP_2 in the case where P and P' are incompatible. For in that case, they would never simultaneously ascribe two such properties to the system in the first place, so that the question as to whether their conjunction or disjunction is meaningful does not even arise on an orthodox approach. (Even von Newmann's brand of orthodoxy, which equates the set of definite-valued projections with those that get assigned probability 1 or 0 by the state, satisfies CP_2 despite the fact that that set contains incompatible projections.)

Third, the intrinsic properties of a composite system should at least *include* the intrinsic properties of its parts. For example, whenever its true (respectively, false) that "The **left-hand wing of the 747** has the property of being warped," then it must surely (classically, anyways!) also be true (respectively, false) that "The **747** has the property that its left-hand wing is warped." It may seem that the difference between these two propositions is inconsequential; but the fact that we take the former to entail the latter makes all the difference to whether we are confident flying in that 747! Since the projection operator analog of a property of a composite system pertaining to one of its parts is $I \otimes P$ (where P is a projection on the Hilbert space of the part on its own), we want to require the following of the set $\mathrm{Def}_{|\psi\rangle}$ (Atom + Cat):

$$\mathbf{CP_3}\text{:}\ P \in \mathrm{Def}_{|\psi\rangle}(\mathrm{Cat}) \Rightarrow I \otimes P \in \mathrm{Def}_{|\psi\rangle}(\mathrm{Atom} + \mathrm{Cat}).$$

This condition still leaves plenty of room for holism about properties in quantum mechanics (which is a feature of all modal interpretations), because it is quite different (*pace* van Fraassen, 1991, p. 290) from requiring that the intrinsic properties of a composite system are exhausted by, or reducible to, the properties of its parts.[5]

Of these three conditions on reasoning classically about physical properties, Dieks, Kochen, and van Fraassen all deny CP_3, Bub denies CP_1, and Healey denies both CP_1 and CP_2. Only van Fraassen (1991, pp. 290–294) and Healey (1989, pp. 74–76) express some discomfort at doing so.[6] We shall now see that these interpretive moves modal interpreters have made are not just optional for them, but forced by their endorsement of MI_1 and MI_2.

3. WHY MODAL INTERPRETATIONS *MUST* ABANDON CLASSICAL REASONING ABOUT PHYSICAL PROPERTIES

The logical structure of the argument is straightforward: assuming CP_1, CP_2, and CP_3, we can derive $\neg MI_2$ from MI_1.

Assuming MI_1, CP_3 gives

$$\{I \otimes P_{|\mathrm{Alive}\rangle_{\mathrm{Cat}}},\ I \otimes P_{|\mathrm{Dead}\rangle_{\mathrm{Cat}}}\} \subseteq \mathrm{Def}_{|\psi\rangle}(\mathrm{Atom} + \mathrm{Cat})$$

[5] A natural formulation of *that* requirement in this context would be $P \in \mathrm{Def}_{|\psi\rangle}(\mathrm{Atom} + \mathrm{Cat}) \Rightarrow P = P' \otimes P''$, where $P' \in \mathrm{Def}_{|\psi\rangle}(\mathrm{Atom})$ and $P'' \in \mathrm{Def}_{|\psi\rangle}(\mathrm{Cat})$, which, if anything, is more like a converse to CP_3. (In fact, CP_3 in conjunction with CP_2 readily entails this latter requirement, *but with the implication going from right to left.*)

[6] In fact, Healey finds himself having to deny, not just CP_2, but the even weaker claim that the propositions about intrinsic properties of a system form a partial Boolean algebra. This comes about as a result of his denying what he calls 'property intersection': essentially, that if two different (necessarily compatible) projections in the Boolean algebra generated by some observable's spectral resolution have intersecting ranges, and those projections represent intrinsic properties of the system, then the projection onto their intersection also represents an intrinsic property.

I should also note that the properties assigned by Kochen and Dieks to any system form a Boolean algebra of projections, therefore they cannot satisfy CP_1 since the set of all projections assigned probability 1 by the state of a system contains incompatible projections. However in my paper (1995) I showed that the property sets of Kochen and Dieks can be enlarged to satisfy CP_1 while still at least forming an ortholattice, i.e. satisfying CP_2. So what seems essential here is their rejection of CP_3.

We also know from CP_1 (and CP_2's requirement of closure under $\perp$) that

$$\{P|PP_{|\psi\rangle} = P_{|\psi\rangle} \text{ or } = 0\} \subseteq \text{Def}_{|\psi\rangle}(\text{Atom} + \text{Cat})$$

So by CP_2, the ortholattice generated by the union of sets

$$\{P|PP_{|\psi\rangle} = P_{|\psi\rangle} \text{ or } = 0\} \cup \{I \otimes P_{|\text{Alive}\rangle_{\text{Cat}}}, I \otimes P_{|\text{Dead}\rangle_{\text{Cat}}}\}$$

must be contained in $\text{Def}_{|\psi\rangle}(\text{Atom} + \text{Cat})$. All we need to show is that this ortholattice is in fact $\{P(\text{Atom} + \text{Cat})\}$, hence we have $\neg MI_2$.

It suffices to show that all *one-dimensional* projections of the system Atom + Cat can be generated from elements in either of the two sets in the union above, since these projections are the generating atoms of the full ortholattice $\{P(\text{Atom} + \text{Cat})\}$.[7]

Since $|\psi\rangle$ is an entangled state, it must live in a Hilbert space of at least four dimensions; but without loss of generality we may assume that to be exactly four (since the argument readily generalizes to any higher dimension). Because the ortholattice operations on projections directly correspond to subspace operations in the Hilbert space of $|\psi\rangle$, I will switch freely between speaking of projection *operators* and their *ranges* (i.e. corresponding subspaces), using the same notation for both.

For state $|\psi\rangle$ we took $0 < w_1 \neq w_2 < 1$, thus we must have

$$(I \otimes P_{|\text{Alive}\rangle_{\text{Cat}}})P_{|\psi\rangle} \neq P_{|\psi\rangle} \text{ and } \neq 0, \qquad (I \otimes P_{|\text{Dead}\rangle_{\text{Cat}}})P_{|\psi\rangle} \neq P_{|\psi\rangle} \text{ and } \neq 0$$

So, geometrically, we are starting with two orthogonal planes (the 'alive' and 'dead' planes, if I can say that) in the ortholattice, both skew to ray $P_{|\psi\rangle}$, as well as $P_{|\psi\rangle}$ itself, and all rays orthogonal to it. We need only focus on one of the planes, say $I \otimes P_{|\text{Alive}\rangle_{\text{Cat}}}$.

Consider a ray $P_{|\phi\rangle}$, inside the plane $I \otimes P_{|\text{Alive}\rangle_{\text{Cat}}}$, that is also skew to $P_{|\psi\rangle}$. Since we can write $|\phi\rangle = |\phi_\psi\rangle + |\phi_{\psi^\perp}\rangle$, with $|\phi_\psi\rangle$ in the ray $P_{|\psi\rangle}$ and $|\phi_{\psi^\perp}\rangle$ orthogonal to that ray,

$$P_{|\phi\rangle} = (P_{|\phi_\psi\rangle} \oplus P_{|\phi_{\psi^\perp}\rangle}) \cap (I \otimes P_{|\text{Alive}\rangle_{\text{Cat}}})$$

so $P_{|\phi\rangle}$ must be in the ortholattice, too, as well as $I - P_{|\phi\rangle}$.

But now *all* rays in the three-dimensional subspace $I - P_{|\phi\rangle}$ must be in the ortholattice by exactly the same sort of argument. For considering any such ray $P_{|\alpha\rangle}$ that is not already in the ortholattice by virtue of being orthogonal to $P_{|\psi\rangle}$ (so $P_{|\alpha\rangle}$ is a ray in $I - P_{|\phi\rangle}$ *skew* to $P_{|\psi\rangle}$), we can always write $|\alpha\rangle = |\alpha_\psi\rangle + |\alpha_{\psi^\perp}\rangle$, yielding

[7] The argument from this point onward is a variation on an argument Jeff Bub and I arrived at in correspondence, though its application here as a constraint on modal interpretations is novel and not necessarily endorsed by Bub.

$$P_{|\alpha\rangle} = (P_{|\alpha_\psi\rangle} \oplus P_{|\alpha_\psi\perp\rangle}) \cap (I - P_{|\phi\rangle})$$

(This intersection does genuinely produce the ray $P_{|\alpha\rangle}$ and not the plane $P_{|\alpha_\psi\rangle} \oplus P_{|\alpha_\psi\perp\rangle}$ again, since that plane cannot be properly contained in the three-dimensional subspace $I - P_{|\phi\rangle}$ if $P_{|\phi\rangle}$ is skew to $P_{|\psi\rangle} = P_{|\alpha_\psi\rangle}$.)

Taking stock, then, we have in the ortholattice the rays $P_{|\psi\rangle}$, $P_{|\phi\rangle}$ (skew to $P_{|\psi\rangle}$), and all rays in each of the three-dimensional subspaces $I - P_{|\psi\rangle}$ and $I - P_{|\phi\rangle}$. It now follows that *all* rays in the four-dimensional Hilbert space of the Atom + Cat system must be in the ortholattice.

For let $P_{|\beta\rangle}$ be a ray not already found to be in the ortholattice. Since we can decompose $|\beta\rangle$ in two *distinct* ways as $|\beta\rangle = |\beta_\psi\rangle + |\beta_{\psi^\perp}\rangle = |\beta_\phi\rangle + |\beta_{\phi^\perp}\rangle$, we can get ray $P_{|\beta\rangle}$ as the intersection of two planes generated by orthogonal rays already in the ortholattice:

$$P_{|\beta\rangle} = (P_{|\beta_\psi\rangle} \oplus P_{|\beta_\psi\perp\rangle}) \cap (P_{|\beta_\phi\rangle} \oplus P_{|\beta_\phi\perp\rangle})$$

The only case in which this argument breaks down is if, perhance, the two intersected planes coincide, intersecting in the plane again rather than the ray $P_{|\beta\rangle}$. This will happen only if $|\beta\rangle$ is in the span of $|\psi\rangle$ and $|\phi\rangle$. If so, then consider $|\phi'\rangle$, obtained by rotating $|\phi\rangle$ about $|\psi\rangle$ out of the subspace they span. Since $|\beta\rangle$ is *not* in the span of $|\psi\rangle$ and $|\phi'\rangle$, and $P_{|\phi'\rangle}$ is in the ortholattice already (just set $|\beta\rangle = |\phi'\rangle$ in the argument just given), let $P_{|\phi'\rangle}$ now play the role of $P_{|\phi\rangle}$ throughout the above arguments to get $P_{|\beta\rangle}$ into the ortholattice. QED

4. CONCLUSION: HOW HIGH IS THE COST FOR MODAL INTERPRETATIONS?

By the nature of the project, any interpretation of quantum mechanics will have its own story to tell about the behavior of physical properties. Hidden variables remove the radical conceptual breakdown required by orthodoxy, but at the cost of explicitly introducing contextualism and nonlocality. Modal interpretations do not pay that price, but are now seen to have to pay another: at least one of CP_1, CP_2, or CP_3 must be rejected.

I do not know which of these is easiest to give up without destroying the initial attraction of the modal interpretation's 'hybrid' orthodox/hidden-variable approach. But if I were forced to choose right now, I would opt for the way Bub (1994) is able to deny CP_1 (without also having to reject CP_2 or CP_3). For he seems to be able to do so *without* sacrificing one of the central intuitions behind CP_1—that when we have a prediction with certainty, there must be *some* intrinsic property present in the system to ground the validity of that prediction. The parting of ways between Bub and CP_1 comes about because, for Bub, there is always one 'preferred' observable (which is most naturally taken to be position) whose dynamical behavior explains the predicted values found for all the other observables by being the observable through which all those others are measured. So Bub has no need to go as far as CP_1 does in attributing a preexisting value to *each and every* observable which happens to have a value certain to be found on measurement.[8]

ACKNOWLEDGMENTS

I would like to thank my colleagues William Demopoulos and John L. Bell, as well as audiences in Cambridge and Oxford to whom I initially subjected these ideas. Thanks also to Guido Bacciagaluppi, Dennis Dieks, and Jeffrey Bub for many stimulating discussions while at the IQSA meeting in Prague, and the Social Sciences and Humanities Research Council of Canada for making it possible for me to attend.

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[8] Essentially the same kind of thing happens in Bohm's hidden-variable theory, which may be contrasted with the sort of 'naive' hidden-variable theory discussed in previous sections in which *all* observables are attributed preexisting values.