Interpreting State Reduction from the Practices-up[1]

Alberto Cordero

CUNY—Queens

The search for a coherent and fertile interpretation of quantum mechanics [QM] with collapse of the wave function is currently a hot topic. This paper focuses on the following sets of related issues: 1) In what sense, if any, do collapse theories constitute a view of the quantum world induced "from the practices-up"? [Here and throughout the paper the term "a view from the practices-up" will mean a view induced from the practices of scientists working on specific problems.] 2) What general description does a collapse variant of QM yield of the physical world? What interpretative problems, if any, does it solve? How exactly does it differ from current mainstream versions of QM? What problems does it face? How serious are these problems in light of current background knowledge?. 3) In our present scientific and philosophical circumstances, what, if anything, makes the search for collapse theories an attractive program? 4) What would the legitimacy of such a search imply with regard to the scope and limits of conceptual revisions within science?

1. Introduction

Post-Bell physics lends renewed credibility to the fundamentality of the quantum algorithm (see, for example, the excellent collection edited by Cushing & McMullin, 1989). And yet, how is one to interpret this result? Realistically understood, the quantum algorithm encourages such notions as objective quantum holism (non-separability), property indeterminateness, and quantum chance. A major difficulty with a realistic interpretation of QM in these terms, however, is that it faces the notorious "measurement paradox", a problem created by the postulation of a single universal "linear" mode of evolution for the quantum state of individual systems. For, as Wigner (1963) taught us long ago, the linear mode is incapable of resolving the superpositions and entanglements it generates in "Schroedinger's cat" and EPR situations. The measurement paradox is generally acknowledged as the single most outstanding problem in the philosophy of physics for the realist.

None of the "official" interpretations of QM available so far seems satisfactory, with the result that objectivist anti- realism (conspicuously, the philosophy of Van Fraassen), or relativist "internalism" (in, for example, Putnam's sense (1981)) become increasingly attractive options. [Other intriguing initiatives include Bohm & Hiley

PSA 1990, Volume 1, pp. 263-275

(1984) and Bell (1987), p. 55]. The Bell experiments, presented in this context, emphasize the notion that in some fundamental way standard QM is correct and that the realist is in trouble unless one can respond to the measurement paradox in a coherent way. Can the realist address this paradox at all within the conceptual framework provided by the concepts of non-determinateness, non-separability and objective chance?

Traditionally, philosophers have turned to axiomatic studies for help with regard to the above issues (conspicuously, masterful presentations by Von Neumann, Mackey, Jauch, and Kraus, to mention some of the most important). Today, however, there is a growing feeling that the formalist foundational program cannot really cope with the measurement paradox, despite the unusually high levels of cleverness and hard work that have been, and are being, invested in it. We are compelled to reject the notion of a universal law of evolution for the whole of physics; yet, can we do this in a convincing way? Is there an alternative to the standard version of the theory?If so, where is one to look for it?

1.2 Suggestions from the Practices-up

Research areas that suggest themselves as sources of inspiration for the realist are the practices of atomic and nuclear physics, quantum chemistry and cosmology, as opposed to the significantly more abstract and formalistic approaches common to standard foundational studies. Although this level of QM is the locus of virtually all the scientific and technical success of modern physics, it is a field largely disregarded by philosophers. However, if we agree that the legitimacy of scientific concepts is not to be decided on a priori grounds, but rather by seeing whether science requires those concepts to go about its business, then we philosophers should get more interested in the study of prospective structural explanations taken from the practices of physics. [Following Hughes (1989), a structural explanation is one that makes explicit a basic structural constraint that events in the field of study are held to satisfy].Two specific examples will be analyzed shortly. Of course, the suggestion that the abstract mathematics of standard QM may be missing some relevant physics is not new, but prior attempts to study the matter appear to be so tinted by background global expectations that a fresher approach might do the subject good (the penetrating, yet philosophically biased, contributions of Feyerabend or Cartwright are cases in point).

Can one reconstruct a coherent non-standard quantum dynamics from the practices of quantum physics in the above sense? If so, how promising is it relative to the standing interpretative difficulties of QM? I want to consider two specific suggestions relevant to the "measurement problem"; one from the study of nuclear decay, the other from the study of electro-molecular interactions.

2. Hints of Objective Collapse: Nuclear Decay

Consider the phenomenon of alpha-particle emission from nuclei in their ground state, as in the decay:

$$_{92}U^{238} \rightarrow {}_{90}Th^{234} + {}_{2}He^{4} + 4.2\ \mathrm{MeV}$$

Notice how standard single-system QM fails to account for this case. According to the usual presentation, the alpha- particle in the right hand side of the reaction is initially trapped in a U^{238} potential well that allows for barrier penetration ("tunneling"). Governed by the linear Schroedinger equation, the alpha particle never localizes; it merely goes on expanding, until a relevant measurement is performed.

Think, however, of the following implication. Physicists agree that uranium atoms date from about 5 billion years ago. If so, a simple calculation reveals that a typical present size for the "outer wave component" of any of those atoms (corresponding to an alpha-particle at 4.2 Mev) must be several million light-years long. If we now follow Born's rule and the standard formalism of QM to calculate the probability of finding any U^{238}-based alpha particle within a region the size of any manageable apparatus during any manageable interval of time, we get a value that is outrageously small compared to the empirical findings (the theoretical calculation turns out to be wrong by about 45 orders of magnitude).

Initially at least, therefore, the narrative that accompanies the practices of nuclear physics would seem to encourage, if anything, instrumentalism with respect to single-system interpretations of quantum theory. At any rate, the "working-level" story just outlined is not even coherent, but a simulacrum explanation in Cartwright's sense (Cartwright 1983). In the standard explanation (see, for example, Cohen 1971), an alpha-particle in an ordinary "nuclear well" is said to move more or less freely within the nuclear well until, upon reaching the surface (materialized as a potential barrier), it encounters a change of potential. When this happens, the alpha-*particle* is either reflected or transmitted, according to an objective probability rule based on the ratio of the wave function intensities in the regions immediately after and before the barrier (penetration coefficient P). From this point onwards, however, the story changes and becomes almost completely classical. The alpha-particle, we are told, is reflected back and forth a number of times into the nucleus, indeed P^{-1} times "on average", with the implication that the average time T_0 required for an emission of this sort is given by the average time taken by each bouncing multiplied by the average number of internal reflections derived from the penetration coefficient.

The problem with the above story is, of course, its almost total incoherence with respect to many things we now know about nucleons and nucleon aggregates. Surprisingly enough, however, this "crazy story" leads to many good estimates of decay rates for various nuclear processes. For, as a matter of *empirical law*, it is found that the experimental probability of emission per unit of time agrees rather well with the value yielded by the "semiclassical" potential-well model of nucleon emission just recounted.

Why does the seemingly incoherent story presented in standard textbooks lead to correct estimates of many decay parameters? We may play safe and take the decay laws as structural elements. Or, at greater risk, we may venture a deeper explanation. Elsewhere I have argued (1989a) that a prospective answer emerges when we consider the case from the point of view of well established shell-model calculations about the internal structure of U^{238} and other relevant information, including empirical findings about decay. One conceptual reconstruction from the practices-up that suggests itself goes like this: the alpha-cluster localizes itself frequently and systematically around the nuclear surface, prompted by its interaction with the nucleus' environment. If so, then it would be approximately correct to use both Born's rule to estimate the probability of decay per collision with the barrier, as well as a classical calculation for the time interval between collisions, based on the group velocity for the alpha-cluster within the nucleus (a reasonable assumption in light of what the best nuclear structure calculations reveal about the relative localization of the alpha-cluster inside U^{238}). On the other hand, when a localization occurs outside the nucleus, the alpha- particle, now free, should initiate a wave function expansion in coordinate space, in accordance with the standard linear equation. Since the expansion in question takes place fast, the process allows for such possibilities as "beam splitting" and all the associated interference phenomena.

2.2 Electro-Molecular "Account" of a Measurement Interaction

Another major suggestion of objective wave function collapse comes from the construction of many basic apparatus. Consider, for example, the following system for measuring the position of incoming electrons. An electron's passage is intercepted by means of an appropriate luminescent screen and the appearance of a flash on the screen is taken to determine its location.

One problem with the standard version of QM is that it even fails to make this contraption relevant. Its linearity insures that the spreading-out of an electron's wave function continues indefinitely beyond the moment it reaches the screen. Furthermore, as the electron reaches the screen, a "Schroedinger's cat"-like superposition of screen-electron states is generated, and this superposition cannot be eliminated from the picture without making measurement something both fundamental and magic in physics. In Von Neumann's interpretation, for example, human consciousness is responsible for the collapse. So, we can heroically join most of the academic establishment and make our philosophy an exploration of the possible world in which Von Neumann's QM is true. Alternatively, we can attempt to make measurement contraptions intelligible in less ambitious terms, from the practices-up.

A coarse narrative of the engineer's "rationale" for the apparatus in question may be extracted from such standard textbooks as French and Taylor (1978) and Alonso and Finn (1968). The incoming electron, we learn, does the following two things simultaneously: 1) it induces state perturbations in the molecules of luminescent material on the screens; and 2) it entangles itself with those molecules in a complex "Schroedinger's cat"-like state. The particular entanglement that results, however, is "known" to be short lived in the following sense:

A. Quantum states manifest an objective "half-life" which cannot be derived from the standard quantum algorithm without trickery.

B. Some states are extremely short-lived; others are in the thousands of years; some are seemingly eternal.

C. No causal account is given of this process; but we are presented with the following causal correlation:

Prob (transition/interactive environment) > Prob (transition),

where, typically, the presence of a transition is marked either by an energy emission or an energy absorption.

D. Finally, quantum transitions are the subject of a number of well established structural laws.Often these laws are initially suggested by semi-classical calculations and then sharpened up phenomenologically in the laboratory. The average lifetime T of excited atomic states, for example, is approximately given by the law:

$$T = 3\hbar l^3/8\Pi^3 D_0^2 \text{ s},$$

where l is the wavelength of the radiation, D_0 is the quantum dipole moment of for the transition involved. Structural laws dealing with the life of states come from many independent fields. For example, for nuclei with shell structures in the neighborhood of Fe^{57}, neutron emission is characterized by a lifetime T that is governed by the law:

$$T = 3.5\ (E[\mathrm{MeV}]\ \text{proton-mass/emitted-mass})^{-1/2}(A/57)^{1/3} \times 10^{-22},$$

where E stands for the energy of the particle undergoing emission and A stands for the atomic number of the nucleus.

Notice that, in the present formulation, the transition per unit of time is derived from the average life of states, not from time dependent perturbation theory (DPT helps only in the calculation of relative amplitudes prior to transition). The concept of average lifetime explored here appears to be thus as fundamental as the standard concept of linear development. As the latter, it is initially conjectured from a particular type of transition via a semi-classical calculation, in this case of the time required to emit/absorb energy corresponding to the quantum "jump" involved. We shall see shortly how the standard conception of transition (conditioned to the occurrence of "measurement") leeds to different predictions.

The suggestion that objective spontaneous transitions are an integral part of the quantum world is also tied to a background of evidence and practice revolving around the "quantum of action", a phenomenon often represented by means of such old tenets as "you never observe half a photon" or "you never observe half an electron".Put in terms of our apparatus for position measurements, one never observes an electron exciting more than one particular tiny region on the screen. An incoming electron ends up either bound to a molecule, or close enough to one in a new free state. Either way, the excitation picks a particular reaction channel out of the initial superposition of states, a process which, in many common cases, amounts to a relative localization of the electron in coordinate space. Quantum-dynamically speaking, however, "localization" is a contingent side-effect. On the other hand, from the point of view of design, localization is central to the fulfillment of the goal chosen (a position measurement). Hence, the material on the screen and the design of the whole apparatus are selected to suit the task of promoting only those interactions which "localize" the incoming electrons within a chosen degree of precision. Obvious criteria for the design of apparatuses built to measure position include, therefore, favoring molecular radiation in the visible range over other processes, making sure that the average life of the molecular excitations involved are short relative to the subsequent history of the measured electrons, and so on.

The prospective lesson for the realist may, thus, be summarized as follows. The electron-screen interaction involves two competing mechanisms whose conceptual link is not presently well understood. None of these mechanisms is related to "measurements" per se. One concerns interactive entanglement, a process governed by the standard dynamical law. The other concerns a relational propensity to jump from one state or channel to another, a process responsible for bringing about objective transformations of state in configuration space.

Still, the above reading is not the only, nor even the most popular, suggestion one can pick up from the practices of physics. At present, the most popular reading of practical physics is probably instrumentalist with respect to single-case QM. Nevertheless, I think the fact that a fairly coherent concept of objective average lifetimes for quantum states arises coincidentally from several independent branches of quantum physics makes it worthy of detailed philosophical exploration, particularly if one compounds this exercise with the further exploration of the foundational issues outlined in subsequent sections of this paper.

3. A Dynamics from the Practices-up

Guided by the above commentary, and following the practices of quantum physics closely, I suggest that we have reason to reconsider quantum theory in the following specific terms. In what follows, I shall make liberal use of statistical equations for the density operator. It will become apparent that this is a mere matter of convenience which in no way denies primacy to the corresponding equation for individual systems.

In standard QM, the sole dynamical law is linear and deterministic:

$$\frac{d\rho(t)}{dt} = -\frac{i}{\hbar}[H, \rho(t)] \tag{3.0}$$

The measurement paradox stresses that this law is not enough, and my central point is that by now we have adequate scientific and philosophical motivation to seriously bear in mind an alternative to (3.0) specifically suggested by the practices of physics. It is a view of the quantum dynamics of individual systems that incorporates an objective probability of transition per unit of time, over and above the deterministic Schroedinger- like mode. Restricting ourselves to the one-dimensional case for the sake of simplicity, we can, as a first approximation, express the underlying intuition about this characteristically quantum mechanical mode of evolution in terms of a mapping $\rho \rightarrow T[\rho]$, where $T[\rho]$ represents the final state reached from ρ. A rough approximation in coordinate representation may be given by:

$$\langle q_1 \mid T[\rho] \mid q_2 \rangle = \exp[\pm(\tfrac{\alpha}{4})(q_1 - q_2)^2] \langle q_1 \mid \rho \mid q_2 \rangle, \tag{3.1}$$

where α represents the "phenomenological reconfiguration" resulting from the transition, q is a generalized position variable, and the sign in the exponential distinguishes between processes of relative spatial contraction (-) and expansion (+).Expression (3.1) is a generalization of the representation of measurement transitions developed by Barchielli et al. for strict localizations (1982).

3.1 A Conceptually Freer Stochastic Model

Going back to the operator T in its most general form, if now a probability of transition per unit of time (λ) is assumed to characterize the situation described by the total quantum evolution of states, then (3.0) must be completed by means of a non-linear stochastic term in the following way:

$$\frac{d\rho(t)}{dt} = -\frac{i}{\hbar}[H, \rho(t)] - \lambda(\rho(t) - T[\rho(t)]) \tag{3.2}$$

As already stated, T stands for the transition to another state, thus being really of the form T_{ij}. Although presented in the formalism of the density matrix, equations (3.1) and (3.2) are given an individual system interpretation.

For strict localizations (3.2) reduces via (3.1) to the equation studied in Ghirardi et al. (1986), only now with all concessions to operationalism dropped. The stochastic term often corresponds to a process of state contraction, but not always. The capture of relatively localized free electrons by the surface of a metal, for example, comes to mind as a typical case of state "expansion" in coordinate space.

What (3.2) is meant to represent is two related suggestions from many practices of quantum physics. The first one is that state evolution comprises both the standard mode and spontaneous transitions. The second suggestion is that sponataneous transitions reveal the existence of a primary propensity in nature to undergo changes of state in accordance with certain rules of "quantum chance", as indicated by the examples considered earlier on in this presentation.

Little has been done so far to study the factors involved in quantum transitions, let alone the structure of their correlation in physical processes. One apparent difficulty is the absence of a simple, universal rule for the representation of the non- linear term in (3.2). Notice, however, that the situation here is not very different from that of the standard potential energy term: the two terms require specific modelling for each physical situation. And, in both cases, the required modelling is based far more on a detailed explication of the practices of scientists working on specific areas than on universal rules of any kind. Unlike the standard potential energy term, however, the stochastic term in (3.2) draws no guidance from classical physics: it is strictly a quantum mechanical novelty.

Almost certainly (3.2) is not a truly fundamental equation, but rather an expression whose meaning should not be expected to become really clear until a full theory of spatio-temporal- matter is developed. Yet, it seems presently reasonable to take (3.2) as an approximate description of a "popping" quantum world of spontaneous contractions and expansions in coordinate space, a world of energy levels described by (3.2) in the context of an empirically successful narrative in which irreducible chance is allowed to have, at least, as much of a fundamental status as continuous dynamical evolution in standard QM. If we understand the matter this way, then the process of spontaneous transition is no longer conceived of as a feature in conceptual "need" of reductive explanation to the standard Schroedinger-like evolution, and no fundamental reference to "measurement" needs to be made in QM.

3.2 Testability

Part of the interest of (3.2) lies in the way in which it naturally leads to inequalities by means of which one might put to the test the interpretation of the practices of quantum physics proposed in this paper, at least in principle. For instance, for the special case of localization reactions (Ghirardi et al, 1986), (3.2) yields via (3.1):

$$(\Delta q)^2 > (\Delta q_s)^2, \tag{3.3}$$

$$(\Delta p)^2 > (\Delta p_s)^2, \tag{3.4}$$

where the subscript 's' refers to the corresponding value derived from the Schroedinger solution (λ=0) for the same initial and boundary conditions.

Admittedly, the story recounted in this paper is incomplete at best, but the point is simple enough. The testability of the model represented by equation (3.2) adds support to the notion that we are before a philosophically interesting alternative to standard QM, a generalized revision of the standard theory whose conceptual structure is worthy of further study, despite its current shortcomings.

3.3 The Critiques of Shimony and Albert

The debates generated by non-linear versions of QM, including one special case of (3.2), namely Ghirardi's seminal but rather ad-hoc proposal, are many and cannot be ignored, particularly in the light of critiques raised against them by Shimony and Albert & Vaidman. As we shall see, however, these critiques focus exclusively on the ad-hoc specifics of selected models and thus do not seem to challenge the notion of state reduction I am proposing in this paper.

A difficulty with deterministic non-linear proposals is the tight constraint certain internal-energy calculations put on them (Weinberg 1989a & 1989b, Bollinger et al. 1989). For a simple system like Be^9, for example, experiments by Gahler et al. (1981) put a bound of 3×10^{-15}eV on corrections of the Schroedinger equation of the form $\Psi \ln | \Psi |$.

Thus, according to Shimony (1989a, 1989b), the prospects for a successful non-linear quantum dynamics are bad, because we already know that the deviation of the non-linear theory must be small for systems with few degrees of freedom, and large for systems with many degrees of freedom, in order to account for the transitions we find in nature. This is certainly an important constraint, but, as Shimony admits, by no means a killer to stochastic non-linear proposals.

In the model suggested in this paper, the stochastic deviation is built primarily in terms of the half-life of quantum states, which I attempt to reconstruct from the practices as a holistic concept, indeed one linked to propensities to change from one state to another. Roughly speaking, the propensity in question is proportional to the number of exit channels and channel sources available. For example, in the case of our earlier electron approaching the screens, assuming for the sake of simplicity that the interaction affects just one and the same excitation channel in all the molecules on the screens, the half- life of the resulting entangled state would be inversely proportional to the number of independent molecules involved, estimated at roughly 10^{20}. Since radiative lifetimes of individual systems are found to be typically in the order of 10^{-7}s (French & Taylor 1978), we are talking of electrons that remain in an entangled state with the apparatus for about 10^{-27}s. Schroedinger's cat, with some 10^{23} molecules or so, would be aborted at this pace in less than 10^{-30}s. In the works cited, Shimony is concerned that, since measurements are often accomplished in nanoseconds, the annihilation of competing terms in the superposition must happen quickly (1989b). In the model suggested in this paper it does.

A more general attack against collapse theories has been presented by Albert & Vaidman (1989). Seizing on the ad-hoc choice of collapse parameters in Ghirardi et al. (1986), Albert & Vaidman show that Ghirardi's specific model cannot account for even the simplest measurements of the Stern-Gerlach kind. They then make the larger point that their critique is applicable to collapse theories in general. In my view, the first part of Albert & Vaidman's objection is correct, but their second point is certainly unwarranted. In other words, Albert & Vaidman are right about the failure of Ghirardi-type localizations with regard to the analysis of most measurement situations, for Ghirardi et al. focus exclusively on trajectory-preserving contractions of the center of mass wave function and, in the end, their parametrization of the equation is correspondingly ad-hoc. However, that has nothing to do with the more physical model I am proposing.

To begin with, the alternative considered in this paper is more general than Ghirardi's, and also significantly less ad-hoc (if at all). It is an alternative suggested by a realistic reading of the practices of physics, but without preconceptions beyond that point, a 'NOA' sort of realism (Fine 1989). Its prospective outcome lies in presenting us with predictions that are at odds in some respects with those of standard QM. Unlike the stochastic term criticized by Albert & Vaidman, the one I am proposing is read directly from the practices of quantum physics; its parameters are contextual rather than universal (as said before, far from being a "new problem", this is also true of the standard interaction term). Moreover, the stochastic term in (3.2) springs from physics without *a priori* concessions to "quantum operationalism", trajectories, or indeed any other features lifted from either classical physics or the original positivist ideology that accompanied the birth of QM. My goal is simply to capture the suggestion that quantum transitions reveal the workings of a fundamental probability per unit of time of spontaneous transition between pairs of states, a highly relational feature manifested in the form of "average lifes".

Let us, then, reexamine Albert & Vaidman's Stern-Gerlach apparatus. An appropriate magnetic field "separates" in space the spin-state components of an incoming fermion in a superposition of "spin up" and "spin down" states along a given direction. The spatial routes induced by the magnet lead to two separate luminescent screens, each like the one analyzed earlier on in this paper. It is clear enough that Ghiradi-type contractions fail to do the required job here. What about the variant proposed in this paper?

The stochastic term in (3.2) is not directly related to "contractions" of any kind, but to lifetimes and available energy exchanges. Thus, my analysis of the situation is as follows, taking the particular case of an electron in spin superposition, to make matters precise: As the electron enters the magnetic region, its spin wave function splits in coordinate space. Upon approaching the "up" and "down" screens, the electron entangles itself with the luminescent molecules on the two separate surfaces. As the molecules' uppermost electrons enter into perturbative superpositions involving higher energy states, the total-system's entanglement grows and develops in the standard manner. As with all states, however, this entangled one has an objective lifetime. In this case, the state not only turns out to be "mortal" but, as estimated before, extremely short-lived. The objective half-life of the present compound electron-screens state simply happens to be about 10^{-27}s (again, not as a matter of principle, but contingently so, as a result of the specifics involved). A quantum transition is thus expected to take place very quickly and, because of the specifics of the transitions made available by typical luminescent materials, as a side effect, the electron should end up localized both at a "point" on one of the two screens (a result marked by a light source several angstroms wide, in accordance with a process already described in this paper), as well as on spin-space.

Thus, contrary to Albert & Vaidman's expectations, collapse theories are not quickly ruled out by a "general", let alone "in principle", incapability to deal with typical measurement situations.This is not to say, of course, that one should remain less than very critical about the interpretation I am advancing. But the approach suggested in this paper seems so promising that a detailed and fresher investigation seems quite in order, despite the current shortcomings of collapse theories.

3.4 Collapse and Special Relativity

Another major critical question concerns the coherence of the notion of collapse vis-a-vis special relativity. Fortunately, here contributions by Van Fraassen (1985, 1982), Redhead (1987), Aharanov & Albert (1984), Fleming (1989), Teller (1989), Howard (1989, 1985), as well as some of my own work in progress, suggest that there is no necessary incompatibility between the concept of objective quantum reduction and special relativity.

Taking the lead from post-Bell physics, it would seem quite possible to deny foundational status to classical separability without compromising special relativity. Serious problems appear to result, however, for those theories in which separability is a fundamental assumption, including general relativity (Howard 1985, 1989). On the other hand, one may choose to avoid conflict with general relativity and endorse classical separability, a central element in our present understanding of the continuous point manifold on which both the metric tensor and the basic ontology of the theory is defined. In that case, the price would be the inclusion of something like action at a distance in the picture, as in the proposals of Bohm & Hiley (1984) and Bell (1987).

Other things being equal, an important difference between the special and general theories concerns brute success. Special relativity has proved triumphant within the quantum domain. Indeed, the non-local structures of standard quantum theory have been carried over all the way to relativistic quantum field theories and their generalizations. The success of general relativity in the quantum world, on the other hand, is significantly more problematic: difficult to bring to bear on phenomena, difficult to blend smoothly with quantum field theories, the status of general relativity is by no means transparent as of this writing.

One suggestion seems, therefore, clear. If the advances made in this paper are approximately correct, then the model I am reading from the practices of physics, with its features of non- determinateness, non-separability, objective probability and law-abiding objective quantum chance, would indeed be an interesting contender for a place in our deepest description of the physical world.

4. Collapse Variants and the Growth of Intelligibility

QM has provided material for deep philosophical and historical reflections. At the very least, it has challenged some of our most fundamental assumptions about the limits of scientific knowledge in our tradition. I hope to have suggested how, by interpreting QM from the practices-up, this process of radical revision may be made coherent, many old problems may be transformed and shown to be relics from a more provincial age, and new problems and insights brought into being.

I think the reflections elaborated in this paper provide a fertile framework for the philosophy of quantum theory. The issues implied by this claim are, of course, many and cannot be profitably addressed here, but one of the most central questions may be formulated as follows: What, if anything, are we learning through the scientific rise, however moderate, of collapse views like the one considered in this paper? Here I can only suggest that the ground and context of this question is philosophically very exciting. For one thing, important revisions of such fundamental concepts as 'state', 'having a property', 'individuality', 'probability', 'possibility', 'actuality', 'being real', 'probability', 'instrumentalism', 'realism', and many others are bound together in a network of primarily scientific considerations. For another, the plausibility and coherence of this network seems assisted throughout by physical reasoning rather than a priori or otherwise scientifically external reasoning.. The need for adequate explication here is enormous, of course. The matter is of great importance to those interested in such fundamental questions as the scope and limits of scientific understanding, the contemporary search for objectivity, the reconstruction of realism, and so on.

Still, the considerations above should not be taken to suggest that the revision of QM explored here is already preferable to all others; rather, they should be regarded only as bringing to light the philosophical interest of that proposal in terms of such considerations as coherence (both internal and with regard to the rest of physics), testability, unifying power and fertility.

Note

[1] I wish to thank Dudley Shapere and Abner Shimony for many kind and helpful comments.

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