Physics Essays volume 5, number 2, 1992

What's Going On in Certain Quantum Interference Processes, Really![1]

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Abstract

Prototype quantum phenomena for unbound systems are analyzed from an "objective reality" perspective. Usual models for a quantum object (QO) are shown to be unacceptable. A new, conceptual picture of the QO is proposed. The undetected QO is an extended physical structure, having no public parts yet maintaining extreme structural integrity by virtue of superluminal processes in a unifying private space. No public probe is faster than those private connections unifying the QO. The private space structure is characterized by an evolving set of identity options each related to a public attribute. Probes of the QO stimulate a deciding process over the set of identity options. A double-double aperture experiment shows the QO spans places where it cannot be trapped. The relation of quantum mechanics to the QO picture is addressed. Spontaneous (not stimulated by detectors) reduction of the state vector at large distances is proposed. The QO picture allows a gentle deviation from the predictions of quantum mechanics in exceptional circumstances not yet experimentally explored.

Key words: quantum mechanics, interpretation; objective reality; interference phenomena; quantum object

1. INTRODUCTION

The idea of "objective reality" – hereafter, OR – is the idea that there is a physical world whose existence is independent of human perception or consciousness. This notion opposes the view that "the physical world" is merely a subjective construct in human consciousness. Objective reality also goes beyond ascribing independent reality only to detected structures: it avers that reality encompasses both the observed and the unobserved. One might have thought that acceptance of detected reality would allow a natural extrapolation to include undetected reality, just as one naturally assumes that the rock detected in stubbing a toe existed before its detection. But our experience with quantum phenomena has raised serious doubts about the general validity of such extrapolations and, hence, about the applicability of the idea of OR to physical theory.

Years ago, when the picture of OR founded on classical physics could no longer reasonably accommodate our observations and there was no tangible basis for developing an alternative OR picture, it made eminent sense not to speculate about the nature of OR, but to adopt a pragmatic approach (without any picture of what is actually going on) for correlating the results of observations. The abstract formalism of quantum mechanics (QM) that grew out of this endeavor is sufficiently powerful and mysterious to keep most physicists happily occupied applying it in a myriad of contexts. But it seems to me that once there has been developed a superbly successful set of rules – like QM – for dealing with a wide range of detected reality, then it becomes reasonable to examine what general OR picture is compatible with these rules. In fact, were it not for reliable calculational rules, like QM, there would be no appropriate constraints (except experimental data) in unraveling the nature of OR.

This paper examines prototype quantum interference phenomena from an OR perspective in order to reveal essential features of the physical structures involved. This phenomena-centered approach is in keeping with the consensus for how to uncover OR: Einstein, Podolsky, Rosen: "The elements of the physical reality cannot be determined by *a priori* philosophical considerations but must be found by an appeal to results of experiments and measurements."(1) Bohr: "The extent to which an unambiguous meaning can be attributed to such an expression as "physical reality" cannot of course be deduced from *a priori* philosophical conceptions but . . . must be founded on a direct appeal to experiments and measurements."(2)

Section 2 summarizes prototype experiments for the emission and detection of a quantum object (QO). Section 3 analyzes usual-intuition scenarios for confronting the data and shows their inadequacies. The results imply that the undetected QO is a spreading, extended entity, although the detected QO is highly localized.

Section 4 examines the objections to an extended QO stemming from the prohibition against superluminal object transmission and from the sometimes nonfiring of the detector closest to the undetected QO. Section 5 examines the notion of "physical object" and presents the idea of a primary object: an extended-but-irreducible entity that is not composed of independent component parts.

Section 6 resolves the dilemmas of Sec. 4 and presents a new, conceptual picture of the QO. The QO's identity structure spans both a subregion of the public domain (the space established by all objects) and a private domain (exclusive to the QO). Superluminal processes in the private domain maintain the QO's structural integrity without contradiction to naive relativity requirements in the public space. The undetected QO superposes together a set of public space attributes (identity options) that are not all present in the detected QO. The QO responds to a probe by a decision process over the set of identity options – either the probed subset of the identity option remains actual and the unprobed subset is eliminated, or vice versa. The former choice yields a reduction of the QO into the probing detector; the latter yields an expansion of the QO away from the probe.

Section 7 examines some strange features of the QO. In certain interference experiments the QO actually extends over places where it practically cannot be detected. One striking example is the double-double aperture experiment where a stream of QO's is directed toward a two-holed barrier followed by a second two-holed barrier. The holes in the second surface are arranged to be entirely within regions of maximum destructive interference for the first two-holed surface. Detection of QO's beyond the second barrier indicates that the QO "is" in the second set of holes, although it practically is not trappable there.

Section 8 relates the OR picture for the QO to QM. The state vector is identified with the QO's set of identity options. The detector-catalyzed collapse of an extended QO corresponds to usual, measurement-related state reduction. Deviations from QM predictions may occur if the expanding QO – at large enough distances or after long enough times – cannot maintain structural integrity by virtue of the superluminal, but finite rate, coordination over its identity structure. Hence there may be a spontaneous reduction of the set of identity options *not stimulated by detectors*. Scenarios for spontaneous spin-singlet state breakdown at large distances predict gentle, slight deviations from usual QM.

2. SOME BASIC EXPERIMENTS

We begin with prototype experiments on an identifiable quantum object (QO), which acts like a photon or an electron. The basic equipment includes an EMITTER, which produces and emits, through a small aperture, a very low-intensity stream of QO's with characteristic detected properties and a DETECTOR-RECORDER, which detects the specific variety of QO in a spatially localized region and then records the detection on a SCOREBOARD.

We focus on the time-space localization of the QO and ignore other identifying features (i.e., orientation properties, charge, etc.). For our purposes, the detector-recorder is simply a presence-counter, a machine that "does something": the detector waits until triggered, then signals the recorder which in turn records the results; the detector resets.

The clock in each detector-recorder does not represent sharp time, but time intervals short enough to allow distinguishability between successive triggers. This can be arranged, even for coupled minidetector arrays, by so weakening the emitter intensity that there is an overwhelming likelihood that only one QO is in the entire apparatus for a given trial.

The first experiment is to get acquainted with the basic equipment. Figure 1 is a stylized sketch of a possible configuration. After many trials for fixed configurations we see that:

(1a) No more than one detector fires at a time.

(1b) Not always the same detector fires.

(1c) There is a directional preference for firing depending on the relative orientation of the emitter and the detectors.

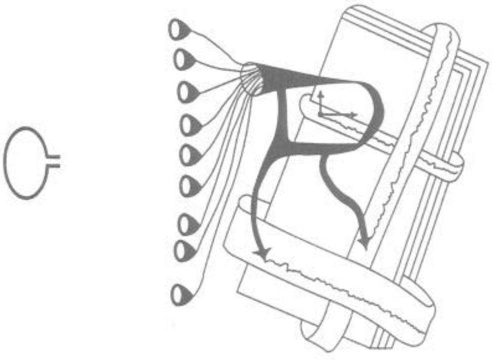

Figure 1. A QO emitter directed toward an array of detector-recorders coupled together to a scoreboard.

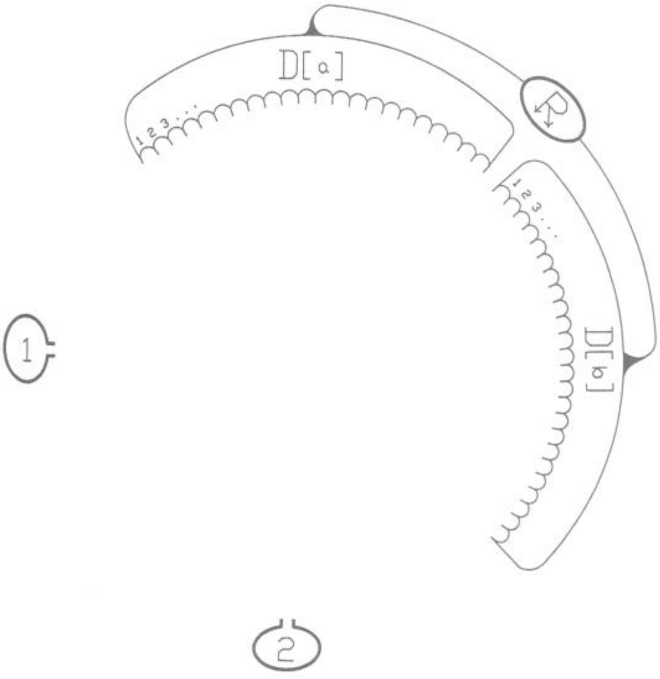

Figure 2. With just emitter1 {emitter2} on, only array D[b] {D[a]} fires.

(1d) For a given configuration the count distribution among the detectors is stable in that the distribution from the first N counts – for very large N – is much the same as the distribution from the next N counts.

(1e) There is no apparent pattern based on cumulative records to predict exactly which detector will fire next; however, the "odds" for a subsequent count at a given detector can be estimated from the distribution of previous counts.

(1f) The count distribution in a plane perpendicular to the "peak" direction (with the highest relative count) is wider for configurations where the distance is greater between the emitter and the plane of detection.

Consider Fig. 2 with two detector arrays: D[a] spans regions [a] and includes detectors D[a_1], D[a_2], . . .; D[b] spans [b] and includes detectors D[b_1], D[b_2], ...

(1g) For the Fig. 2 setup (just emitter1 on): only D[b] fires, not D[a].

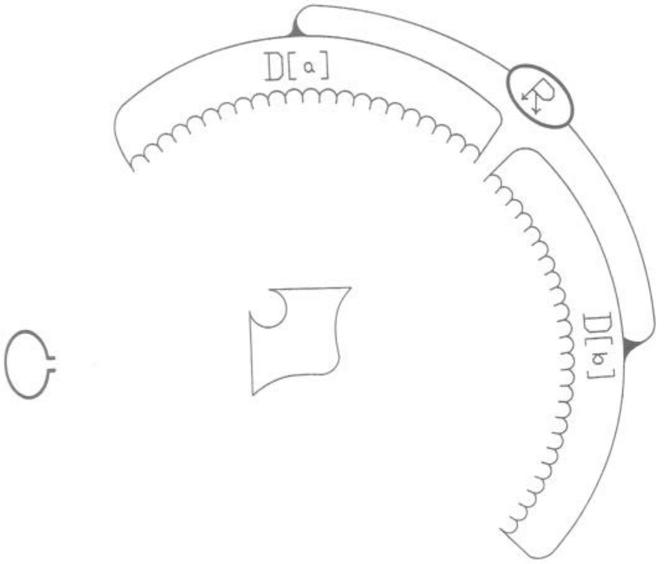

Figure 3.1. A shifter is introduced; only array D[a] fires.

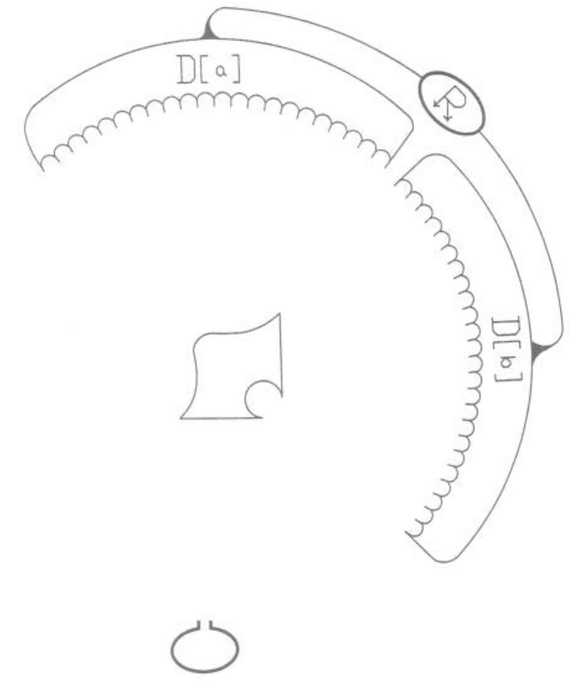

Figure 3.2. A shifter is introduced; only array D[b] fires.

(1h) For the Fig. 2 setup (just emitter$\underline{2}$ on): only D[a] fires, not D[b]. Consider, now, another device called a "shifter."
(1i) For the Fig. 3.1 setup: only D[a] fires, and not D[b].
(1j) For the Fig. 3.2 setup: only D[b] fires, and not D[a].

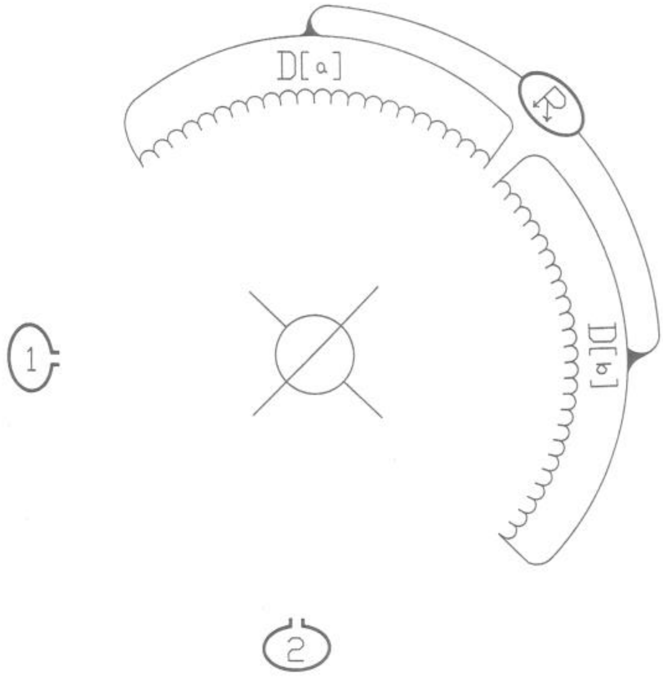

Figure 4.1. A splitter in the Fig. 2 setup. With just one emitter on, both D[a] and D[b] fire with equal frequency.

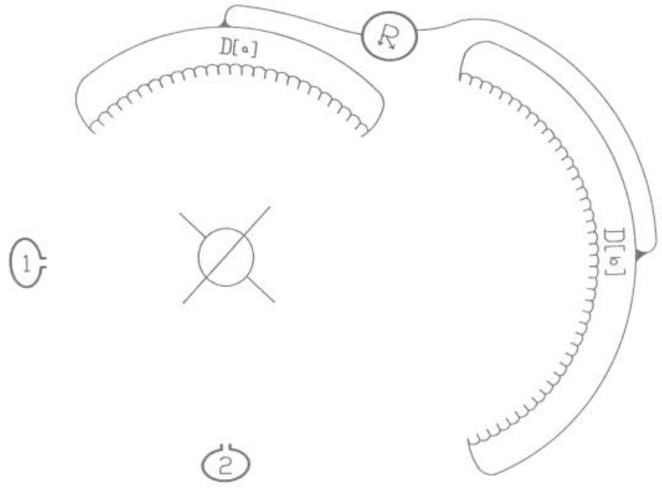

Figure 4.2. Asymmetric configuration. With just one emitter on, both D[a] and D[b] fire with equal frequency.

We do not know directly what processes are occurring to the QO from emission to detection. In fact, the very presumption of an actual undetected QO may be questioned. Is there indeed a QO, or is the term QO no more than a convenient way of referring to a correlation between complicated pieces of equipment called by the prejudicial names "emitter" and "detector"? With no testable model for the QO, this question is tame. But accepting a detected QO (a so-and-so-on) and taking an OR outlook, it is natural to postulate a physical structure – the undetected QO – before the detection process, being careful not to make unwarranted extrapolations of detected QO properties to the undetected QO. The experiments so far suggest the QO travels from the emitter in a certain general direction, which can be altered by a shifter.

Figure 4.1 introduces a "splitter" device. For fixed configurations with one emitter on:

(2a) No more than one detector fires at a time.

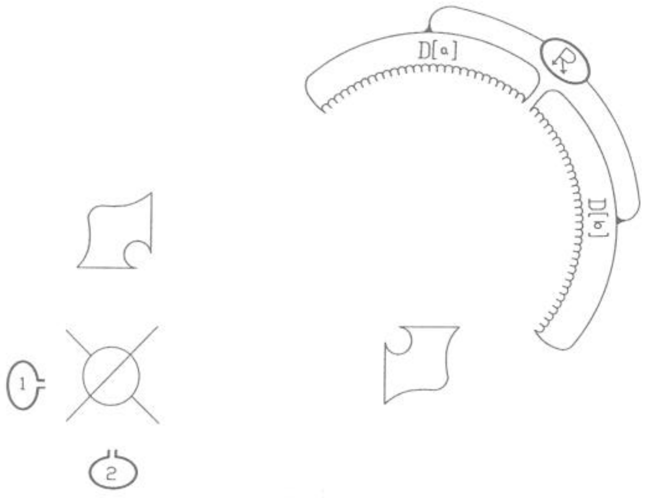

Figure 5. Single-splitter with shifters. With just one emitter on, both D[a] and D[b] fire with equal frequency.

(2b) Not always the same detector fires.

(2c) Detection occurs with equal frequency in D[a] and D[b] in that for a large number N of counts, $N[a]/N \approx 1/2$; $N[b]/N \approx 1/2$, where $N[a]$ $\{N[b]\}$ is the number of counts within D[a] {D[b]}.

(2d) The count distribution within an array is stable in the sense of (1d).

(2e) There is no apparent pattern based on cumulative records to predict exactly which array or detector will fire next.

(2f) For each array there is a peak count direction, and the shape of the count distribution relative to the peak is essentially no different than in the Fig. 2 or Fig. 3 experiments.

(2g) The spread of the count distribution within an array grows with increasing separation between the plane of detection and the splitter.

(2h) Results (2a) to (2g) are unaffected by the arrays' asymmetry, as in Fig. 4.2.

(2i) Shifters, as in Fig. 5, do not affect essential results. The count spread within an array now grows with increasing distance between the detection plane and the shifter aligned with that array.

Now consider a two-splitter interference experiment:

(3a) For the Fig. 5 setup (emitter1 on), add, by trial and error, another splitter (identical to the first) so that only one array fires, say, D[a] and not D[b]. Figure 6 shows this device.[2]

(3b) A null result in D[b] is possible even with asymmetry in the distances between the final splitter and the arrays.

(3c) A null result in D[b] is possible even after adding a "delayer" built of shifters (as in Fig. 7), but this is sensitive to the delayer's size.

The difficulties in precise construction and alignment make the extreme interference pattern – counts in only one array – unattainable in practice. It is possible to achieve an interference pattern over D[a] that is complementary to that over D[b]; that is, minima in the D[b] count distribution correspond to maxima in the D[a] count distribution. But to avoid encumbering the discussion, let us focus on the extreme interference result, since, for the inferences to be made, it is no different in principle than more complicated interference patterns.

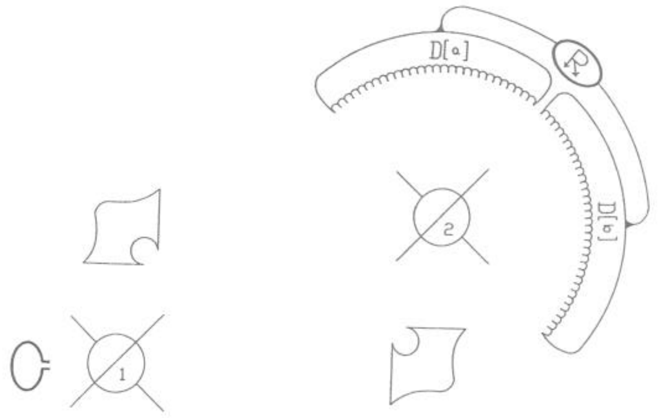

Figure 6. Two-splitter extreme interference; only D[a] fires.

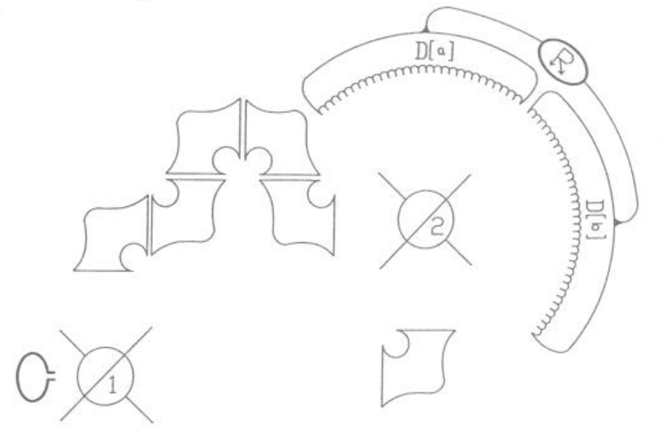

Figure 7. Delayer in two-splitter extreme interference; only D[a] fires.

3. ANALYSIS

For the Fig. 4.1 experiment (emitter1 on), the main processes are:

Process	*Associated Device*
emission	emitter
initial propagation	emitter, splitter
splitting	splitter
final propagation	splitter, D[a], D[b]
detection	D[a], D[b]
recording	D[a], D[b], scoreboard

The propagation processes are associated with regions between devices. Subprocesses (such as signaling in the wires between D[a] or D[b] and the scoreboard) may be added if needed. Shifters, as in Fig. 5, add no essential complication; "final propagation with shifters" involves the splitter, the shifters, and D[a], D[b].

Let us assume that for the QO the above processes are temporally sequential in a very broad sense: emission begins before initial propagation, which begins before splitting, which begins before final propagation, which begins before detection, which begins before recording. Detection is complete after final propagation, which is complete after splitting, which is complete after initial propagation, which is complete after emission. This is rather unrestrictive in that all the processes may occur in a given time interval.

Now we ask, What decides, in the single-splitter experiments, whether D[a] or D[b] will eventually fire, and when is the decision first made?

This is a "loaded" question. One response, undermining its premise, is, No such decision is made, since all the possible alternative outcomes actually happen in every trial, with each performed alternative winding up in a separate, real universe; only one outcome happens "here" (where we are), while the other options each occur "elsewhere" in distinct universes (where we are not). This extravagant OR picture will not be considered here.

The usual-intuition response is a cause-and-effect mechanism: the splitter/QO interaction fixes the choice. The splitter presents the QO with two mutually exclusive directions: either toward [a] or toward [b]. Symbolically this mechanistic proposal may be represented as Scenario1:

$$\mathrm{QO[b]} \xrightarrow{\text{splitter}} \mathrm{QO[a]} \text{ or } \mathrm{QO[b]}, \tag{1}$$

$$\mathrm{QO[a]} \xrightarrow{\text{splitter}} \mathrm{QO[a]} \text{ or } \mathrm{QO[b]}, \tag{2}$$

where, before the splitting process, the input QO has one general direction, toward [b] or toward [a]; the arrow represents the processes after the start of splitting but before detection; and the output QO, before detection, has only one of two general directions. There is no doubt just before detection which array will fire.

Scenario1 includes, not only the particle model in which the undetected QO has the detected QO's localized structure, but also more elaborate models wherein splitting may continue even after the start of the next propagation process.

Scenario1 requires for the Fig. 6 interference experiment: either

$$\mathrm{QO[b]} \xrightarrow{\text{splitter1}} \mathrm{QO[a]} \xrightarrow{\text{splitter2}} \mathrm{QO[a]} \text{ or } \mathrm{QO[b]} \tag{3}$$

or

$$\mathrm{QO[b]} \xrightarrow{\text{splitter1}} \mathrm{QO[b]} \xrightarrow{\text{splitter2}} \mathrm{QO[a]} \text{ or } \mathrm{QO[b]}. \tag{4}$$

Both D[a] and D[b] should count with equal frequency and with equivalent distributions over their respective detectors. *But this is not what happens.* Only D[a] fires and not D[b] (or, more generally, the distribution over D[a] is complementary to that over D[b]). Thus Scenario1 is untenable unless the foregoing argument is invalidated.

Let us cook up a distinction between the QO in the splitting1 process and the QO in the splitting2 process of Fig. 6. This would disqualify using the one-splitter experiment to anticipate (incorrectly) the outcome of the two-splitter experiment. Each splitter has two distinct input directions and two distinct output directions. Consider, then, Scenario2 where

$$\mathrm{QO[b]} \xrightarrow{\text{splitter}} \mathrm{parts[a]} + \mathrm{parts}'\mathrm{[b]}, \tag{5}$$

$$\mathrm{QO[a]} \xrightarrow{\text{splitter}} \mathrm{parts}''\mathrm{[a]} + \mathrm{parts}'''\mathrm{[b]}, \tag{6}$$

where parts[a] has the direction toward D[a], etc. The idea is to exploit the splitter geometry to avoid the difficulties in (3) and (4) and to accommodate the Fig. 6 interference result as follows:

$$\mathrm{QO[b]} \xrightarrow{\text{splitter1}} \{\mathrm{parts[a]} + \mathrm{parts}'\mathrm{[b]}\} \xrightarrow{\text{splitter2}} \text{“output,”} \tag{7}$$

where the "output" is eventually detected as a QO in D[a]. This scenario distinguishes the initial propagation of a unidirectional QO from the intermediate propagation of "parts" with distinct directions. The "output" of splitter2 could depend upon the precise relation between the input "parts" and splitter2. This "output" could not be anticipated from single splitter experiments whose input is a unidirectional QO. Why this "output" of splitter2 isn't designated as QO[a] will later become clear; for now, the prior issue is, What are the "parts"?

Although Scenario2 can handle the interference experiment, the one-splitter experiments become problemic. How are the "parts" and the QO related? Consider the following possibilities:

M1. Each "parts" is a spacially distinct, independent entity equivalent in structure to the QO. This is symbolized by

$$\mathrm{parts[a]} \equiv \mathrm{QO[a]}; \quad \mathrm{parts}'\mathrm{[b]} \equiv \mathrm{QO[b]}. \tag{8}$$

This proposal includes the wave model. The one-splitter experiments, especially the asymmetric versions of Fig. 4.2, pose grave difficulties for M1 which leaves unanswered: (1) Why are both "parts" (each equivalent to a QO) not detected in every trial? One "parts" always vanishes into thin air, a rather unpalatable prospect. (2) Why doesn't the array closest to the splitter fire preferentially? Thus M1 is not viable in making sense of the QO, although the wave model is a useful mnemonic for summarizing interference patterns, regardless of how they come about on a quantum level.

M2. Both "parts" are distinct, independent entities and not structurally identical. Only one of the "parts" carries the essential identity structure of the QO, the remaining "parts" being "something else." That is,

$$\text{either } \{\mathrm{parts[a]} \equiv \mathrm{QO[a]}; \quad \mathrm{parts}'\mathrm{[b]} \equiv \text{something else[b]}\} \tag{9}$$

$$\text{or } \{\mathrm{parts}'\mathrm{[b]} \equiv \mathrm{QO[b]}; \quad \mathrm{parts[a]} \equiv \text{something else[a]}\}. \tag{10}$$

For the Figs. 4.1 and 4.2 (emitter1 on) experiments this implies

$$\begin{aligned} \mathrm{QO[b]} \xrightarrow{\text{splitter}} &\text{ either } \{\mathrm{QO[a]} + \text{something else[b]}\} \\ &\text{ or } \{\mathrm{QO[b]} + \text{something else[a]}\}. \end{aligned} \tag{11}$$

Now the arrays' asymmetry is no problem provided the "something else" cannot influence a QO detector. Scenario1 is salvageable in a practical sense if the "something else" of (11) is *never* seen. But M2 leaves mysterious this undetected "something else." That an independent, spacially distinct entity is produced and yet always remains undetected is a glaring loose end. The "something else" vanishes into thin air – an unacceptable process.

A further puzzle for M2 (and also M1) is the Fig. 7 experiment. If the two independent "parts" become spatially *and* temporally distinct, what guarantees coordination between the separate "parts" in the splitter2 process? The start of the splitter2 process need not be concurrent for the delayed and the undelayed "parts." So how do distinct inputs to splitter2 act together to yield an "output" that is detected as only one QO? These difficulties are also present in the modified proposal, M2′, which includes the particles plus guiding waves model: either

$$\begin{aligned}\{\text{parts}[a] &\equiv \text{QO}[a] + \text{something else}[a]; \\ \text{parts}'[b] &\equiv \text{something else}[b]\}\end{aligned} \tag{12}$$

or

$$\begin{aligned}\{\text{parts}'[b] &\equiv \text{QO}[b] + \text{something else}[b]; \\ \text{parts}[a] &\equiv \text{something else}[a]\}.\end{aligned} \tag{13}$$

Again, the failure to detect the independent entity "something else" mars this proposal despite its other virtues.

M3. Both "parts" *together* constitute a single QO; "parts" are not independent entities. That is,

$$\{\text{parts}[a] + \text{parts}'[b]\} \equiv \text{QO}[a,b], \tag{14}$$

where the undetected QO[a,b] is characterized by *both* directions and a spatially extended domain (encompassing all the "parts").

Scenario2 now becomes

$$\text{QO}[b] \xrightarrow{\text{splitter}} \text{QO}[a,b], \tag{15}$$

$$\text{QO}[a] \xrightarrow{\text{splitter}} \text{QO}[a,b], \tag{16}$$

which still retains the prototype strategy for dealing with interference. Scenario1 is violated unless an expanding, multidirectional, undetected QO *always* spontaneously becomes a unidirectional QO before the detection process. But such a development would lead to interference breakdown. Thus Scenario1 is not generally tenable, even though without it the localized detection becomes mysterious. We now proceed along the route opened by M3, the threat of blind alleys notwithstanding.

4. DILEMMAS

The analysis so far suggests:

(1) The undetected QO may become highly unlocalized and multidirectional.

(2) In the one-splitter experiments there is doubt before the detection process in any given trial which array, D[a] or D[b], will fire.

(3) The detected QO is spatially localized (in a minidetector).

This implies that during detection, the spread-out QO collapses into the localized, detected QO (the so-and-so-on). To take this idea seriously, we must confront two major puzzles.

Dilemma1. How can a highly extended object suddenly become much smaller without violation of the public speed limit c, especially if the object keeps expanding until detection? In the single-splitter experiments, the two arrays can be very far from each other and from the splitter. If the undetected QO[a,b] is greatly extended, how can public superluminal speeding be avoided in a collapse of the bloated QO into just one detector?

Dilemma2. How can an expanding, extended object *not* be preferentially detected by the closest detector array to it? In the asymmetric single splitter experiment (Fig. 4.2 with emitter1 on), how is it that the array closest to the splitter fires only in about half the trials?

These dilemmas rule out models for the QO as a usual extended object for which any component part can start to be detected without coordination with more distant parts, like a cloud, or an expanding balloon, or a tangible day-to-day thing. If QO[a,b] were indeed a usual smeared-out object which collapses by parts[a] initiating detection without any coordination with parts[b] or vice versa, then for the single-splitter experiments, first, problems arise in complying with the public speed limit (1) in notifying the parts distant from the firing detector that no further detection is possible elsewhere, and (2) in the rush of the distant parts to join the fun at the firing detector without their ever being detected on the way. Even a prolonged detection process does not remedy the superfast response time needed to ensure that the QO as a whole winds up in the one detector. Second, the array closest to the splitter would always fire. But it does not!

The public speed limit also rules out those models wherein part of the QO (say, the particle in the particle plus guiding waves model of M2′) jumps back and forth between, or is signaled from, distant spatially separated regions, thus simulating an extended object over a short time interval.

Both dilemmas indicate there is no static, frozen-in-time picture of the undetected QO. At this juncture one may well be tempted to give up reasonable hope of a sensible OR description for the QO.

After all, one way out is simply to abandon a structural OR approach and regard the dilemmas as irrelevant. According to an anti-OR approach, one should not analyze or seek meaning in terms of dubious notions such as OR or undetected QO. The answer to what decides which array will fire in the single-splitter experiment becomes Scenario3: *the decision depends irreducibly on the SYSTEM, the particular configuration of equipment, as an integral whole*. How the choice is made is an unknowable mystery and cannot be discovered by poking around or adding equipment, since that would change the SYSTEM. The choice which array will fire is made during detection. This approach is clear-cut, but cuts off discussion about what is going on. Its advocates would say "useless discussion." This approach focuses on rules for making predictions without the notion of an actual undetected QO. At best, the undetected QO becomes a convenient fiction, a way of referring to correlations within the SYSTEM. If down-to-earth folk insist on asking about physical reality in the Fig. 2 experiment, then the anti-OR response is this: the real objects are the equipment devices and (in a liberal moment) perhaps the so-and-so-on; but not the so-called, undetected QO.

Another less ideological way out is a neutral attitude: maybe the undetected QO is or is not a real thing (who knows?); but describing it as an object is confusing/difficult/futile/unnecessary – take your pick. So why not, if we can, avoid the issue in physical theory? After all, what difference does it make?

Both the anti-OR and non-OR approach to physical theory focus on pragmatic, predictive schemes without regard to hypothetical undetected reality. Undeniably this effort has been tremendously fruitful, as evidenced by the striking successes of QM.

The OR view, on the other hand, strives – without rejecting pragmatism – to develop structural models that "explain" the pragmatic rules in terms of actual entities and processes. The OR advocate stubbornly insists that the QO, undetected and detected, *is* a real object and should play a central role in physical theory. Being boxed-in by dilemmas is symptomatic of conceptual roadblocks anchored in unwarranted, implicit prejudices. Before making explicit these prejudices and resolving the dilemmas, let us first examine a fundamental issue: what is the relation of the notion of "physical object" to OR?

5. PHYSICAL OBJECTS

Around us we perceive all sorts of physical objects, "things." We assign names to objects for various reasons as a matter of human convenience. The question arises, In what sense are what we call "physical objects" objectively real? One could argue that named "things" are no more than convenient mental constructs helping to organize human perceptions. After all, the referential framework for assigning meaning to "chair" or "star" is human consciousness. So on what basis is what is called a "chair" actually a real object, independent of people? Are "things" objectively real or just convenient for human communication?

One reply is the only-one-real-object hypothesis: any "thing" (say, a chair) is a dependent part of the physical world as a whole and is not an independent entity. The world as a whole is actually *one* irreducible, all-inclusive thing; it is the *only* objectively real physical structure.

Another reply is the objective-real-stuff hypothesis: while "chair" is certainly a convenient, organizing mental construct grounded in human experience, chairs are also real objects, since they are made out of real stuff, as are all other physical objects. The existence of real stuff is independent of human perceptions or consciousness. Naming or not naming a physical object is a matter of human convenience; but the object itself is made of real stuff; hence the object is real. This assertion alone is not convincing; however, if an OR-type physical theory based on the notion of real stuff becomes successful, then, even though this is no proof, the success of such a theory would strengthen the claim for real stuff. On the other hand, if a non-OR physical theory avoiding the notion of undetected real stuff is successful, then, even though this is no proof, the success of such a theory promotes indifference to claims for undetected real stuff.

But even a successful theory of real stuff does not close the issue. The questions arise, Just what *is* this real stuff? Out of what is *it* made? Perhaps it, too, is just convenient terminology and not essentially different from other convenient designations like "the moon" or "borscht."

Going back to an earlier era, the response would be the ultimate-stuff-is-point-stuff hypothesis: the ultimate real stuff is point-objects at time-instants. Any physical object may be reduced conceptually into stuff-points at instants, because no thing is smaller than a stuff-point at a time-instant. A stuff-point at an instant is irreducible with respect to any external conceptual reference. No physical or conceptual probe can focus on a part of it, because it is a unit entity with no component parts – unlike everyday objects. There is no ambiguity in conceptually *counting* the stuff-point – it is *one* object and not a collection of objects – from all references. This unity of identity is structural and not just a consequence of a unifying name, such as "chair." Without people, there would be no need for specialized names for various collections of the ultimate real stuff, but there would still be ultimate real stuff.

The successes of classical mechanics reinforced the notion that point-objects at instants were the ultimate real stuff. But the failure of classical physics for quantum phenomena undermines this picture.

The OR approach pursued here subscribes to the objective-real-stuff hypothesis but without commitment to reduction into point-stuff at instants. It allows for *spatially extended* real stuff that is not composed of independent, constituent parts. Let us call "primary object" such a hypothetical, extended entity that persists as an irreducible structure with respect to the world external to it. No physical or conceptual probe could focus on part of a primary object, since it is not a collection of separate, interrelated parts. Since a primary object would in all circumstances act as *one* thing, its unity of identity is not just semantics, but is actual and structural.

The idea of an extended, yet irreducible thing conjures up oxymorons like "extended point." It opposes the common assumption that if an object spans over a region including "here" and "there," then part of it must be "here" and "part" of it must be "there." What transforms the notion of primary object into more than a take-it-or-leave-it speculation is, as we shall shortly see, that the QO's behavior is consistent with interpreting it as a primary object.

6. MAKING SENSE OF THE QO

In the domain common to all physical objects – the public domain or the public world – the QO is a physical structure, which, when undetected, encompasses a growing spatial region and which, when detected, is localized. Consider the Fig. 4.1 experiment (emitter1 on) with D[a] and D[b] far from the splitter. Just before detection the QO extends over [a] and [b] the public space regions of the arrays. In every trial only one object is detected – either in D[a] or in D[b]; hence there must be a physical connection *for the QO* between [a] and [b]. The speed limit *c* for signaling/object transmission in the public domain rules out a public connection for the QO between [a] and [b], that is, by a physical process exclusively in the public domain. But the evidence points to a link for the QO between [a] and [b]. If so, there must be a *private* connection for the QO between [a] and [b] that is not limited by the public speed limit, but, nevertheless, does not wreak havoc with the prohibition against relative superluminal public speeding between two objects.

This private link means that the structure "space" of the QO is not limited to the public space (since the link for the QO between what are two separate regions [a] and [b] in the public space is not a public process). A private space for the QO does *not* necessitate that the public space be richer in a universal fashion for all physical objects; but rather, *for the QO* there is an additional richness in its own identity structure, which maintains a private superluminal connection between two disparate public space regions. This is *not* a convoluted assertion that there is a spooky action-at-a-distance between two widely separated public objects via a hidden superluminal process not in usual space-time. Nor is the claim that one identifiable part of an object is in [a] and another part is in [b] with a private superluminal link between them. Such unacceptable connections between *two* or more widely separated, things (or parts of things) violate the public relative speeding rule.

A superluminal private connection over *one* irreducible system does not contradict Einstein's rock-bottom enjoinder(3): "But there is *one* assumption which, in my opinion, we should retain under all circumstances: the real factual state of the system S_2 is independent of what is done to the system S_1 where S_1 is a system that is spatially separated from S_2."

To visualize the idea of a private connection, consider a play world where, for a small enough time interval, the public space common to all playthings is a two-dimensional surface, say, a sphere. Every play object has a public presence over a subregion of public space; however, the full identity structure of a play object may reach off the ball's surface. The identity structure of a usual plaything is limited to public (on the surface) connections, and its public extent is shown in Fig. 8 by a connected black subregion on the public surface. The structural domain of a quantum play object is not identical to its public presence domain (shown by one *or more* disjoint dotted regions on the surface), but includes private unifying connections off the public surface. The envelope of these private connections is represented by bubbles or tubes outside or inside the public surface.[3]

A public speed limit constrains the range on the public surface over which there can be interaction between two playthings during the short time interval. Can a superfast, private connection over large distances possibly be consistent with the limited range for public connections between two things? One might argue that if part of a thing is also a thing, there cannot be, over a short time interval, any interaction between two widely separated parts of a thing, because this would violate the limited range for public connections. But the premise of this argument rests on hypothetical reducibility into public parts as a necessary attribute of all objects. Why need this be so? It needn't be so for QO's!

The extended QO jars our sensibilities by not conforming to the prejudice that a physical system which spans over two public space regions, [a] and [b], necessarily involves at least two public subsystems (component objects): one identifiable object in [a] and another in [b]. The QO shatters this prejudice *without undermining the relative speed restriction on public links between two separate objects.*

To resolve Dilemma1, we must admit that the QO is always *one* irreducible object with respect to any public reference, that despite its public extension, the QO is not reducible into spatially distinct public parts. There is, then, no public relative speeding within the QO's public extent. Also, the superfast collapse during detection is not a race of independent public parts whizzing towards a detector and is never "seen" as such; the QO collapses *as a whole.*

Certainly the QO acts, in any public probe, as a unit structure without public constituents. It is a primary object, irreducible in public space; a world in itself whose identity structure is maintained objectively (albeit not entirely in the public domain). Any process in the public domain to probe the QO occurs *slower* than those internal-to-the-QO processes – "private-world processes" or "intra-actions" – which maintain the identity structure of the QO as a single unit. The QO's unity is so extreme that with respect to any public reference, no subregion of the QO's public extent contains a separately identifiable part of the QO, even if the QO's public extent is very great.

The extended QO is very different from a usual object, like a stick. The two ends of a stick each span separate public space regions and are separate public parts of an extended system. Thus a stick has public component parts. A stick is not objectively *one* thing – the categorization "one system" for it or even the name "stick" is only a matter of human convention. For a small enough time interval, the two stick ends are independent systems with no superluminal connection between them, and they can be distinguished from each other by certain public processes.

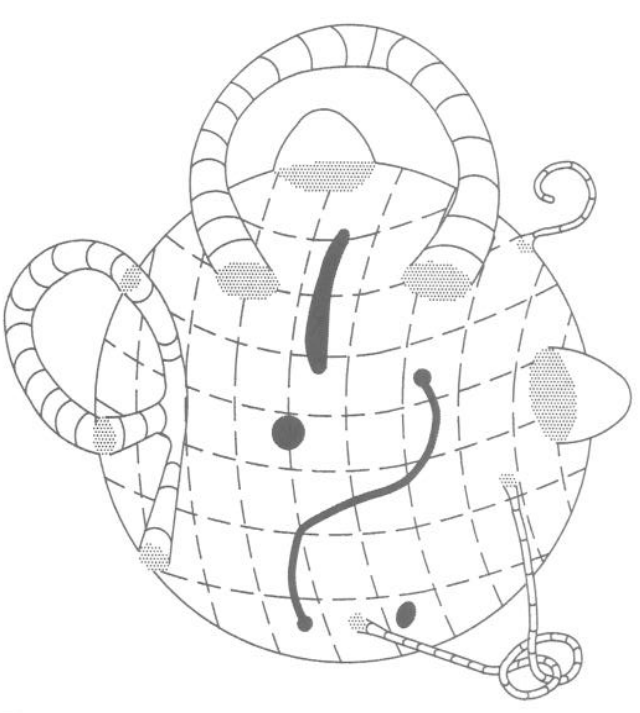

Figure 8. Spherical play world over a short time interval. Black areas on the surface bound everyday playthings. Dotted areas with off-the-surface private connections bound play analogs of QO's.

The QO, on the other hand, is one irreducible entity for any public space process. This is not simply a practical limitation in that the fastest probe never manages to reveal distinct public parts for the QO, but, rather, reflects the actual lack of distinction *for the QO* between public regions that are disparate for a usual localized reference. There are no public component parts for the QO. Nonetheless, the QO is a physical structure with a public presence.

The QO's lack of public parts is also crucial for handling Dilemma2. In the Fig. 4.2 experiment (emitter1 on) there is doubt, before the detection process in any trial, which array, D[a] or D[b], will fire. Suppose the QO reaches [a] and not yet [b] so that D[b] is not yet involved in any goings on with the QO. If the QO had public parts, then the presumed component in [a] would be required, in roughly half the trials, *not* to initiate QO detection in D[a]. This would mean that an identifiable object – the presumed component in [a] – when, in effect, asked by a probe, Are you here in [a]?, could respond with a contradiction, No, I'm not in [a]. Thus the presumption of public QO parts is unacceptable. Eliminating it avoids the contradiction as follows: The QO has a public extent including [a] but not limited to [a]. If a probe asks, Are you here in [a]?, the QO's response is, No, I'm not in [a]; I'm elsewhere. What this implies for the nature of the QO is addressed further on.

The usual notion of "object" assumes that physical structure is exclusively public domain structure. The usual notion fails to accommodate the QO. Thus the choices are:

(1) To deny meaningfulness for the notion of independent-of-people, "physical object" and ignore reality questions for any "so-called" object.

(2) To retain the usual notion of "object" whereby all extended objects

are conceptually reducible to public component parts, thus rejecting the undetected QO as an actual object. Both (1) and (2) limit physical theory to operational rules for correlating the results of human perceptions.

(3) To extend, as is suggested here, the notion of physical object to include the undetected QO.

A joke is in order. The following one illustrates how people explain new things.

A: How does a telegraph work?
B: Instead of a wire, imagine a very long dog with its head in Jerusalem and its tail in Tel Aviv. Pat the dog's head in Jerusalem and it will wag its tail in Tel Aviv. Pull the dog's tail in Tel Aviv and it will bark in Jerusalem.
A: I see. But how does wireless telegraphy work?
B: The very same way, but without the dog!(4)

We must not assume that the common intuitions based on experience with familiar public world structures will serve as reliable guides for mapping out the QO's private world. To describe the public and private domain structure of the QO without falling into a false, public parts picture will require an abstract language that has plenty of room for extraordinary, outlandish structures.

Let us symbolize by [R] the public subregion spanned by the QO. Region [R] does not exhaust the structural domain of the QO, which also has a unifying private domain. Region [R] is extended – not from human ignorance of a more precise position specification of the QO – but because the QO is a structural unity, extended over a size-varying [R]. Suppose $[a_i]$ and $[b_j]$ are among the detector regions encompassed by [R]. Neither $[a_i]$ nor $[b_j]$ separately bound an independent public structure other than one of the detectors, even though one thing, the undetected QO, spans both $[a_i]$ and $[b_j]$. In the QO's detection, [R] is drastically contracted by a superfast physical process within the QO *as a whole*.

Let us call "public identity option" a possible public attribute of the detected QO; for example, a collapsed public presence domain such as $[a_i]$ or a subregion of $[a_i]$. Each identity option is not assignable to a public substructure of the QO; there are no public QO parts nor are the identity options public objects; they are constraining aspects of the QO's structure, and the entire set of identity options characterizes the QO as a whole. The undetected QO combines in *one* object a set of public identity options that cannot all be actual in one detected object – a detected QO is never associated with both $[a_i]$ and $[b_j]$, but with only one of them. Yet both $[a_i]$ and $[b_j]$ may be position identity options for the undetected QO. This superposition of identity options is maintained by virtue of the private space unifying the QO over [R].

$D[a_i]$ establishes a public space process that probes whether a QO can be restricted to those position identity options bounded by $[a_i]$. This is reasonable, since $D[a_i]$ firing precludes detection of the QO outside $[a_i]$. Suppose, in the Fig. 4.2 splitter experiment (emitter$\underline{1}$ on), [R] first reaches [a], since [b] is more remote. The QO develops a range of identity options. If $D[a_i]$ fires, [R] has collapsed into $[a_i]$. In the detection process the selection of a particular identity option eliminates the other identity options. This "choosing" process is not one wherein a bloated QO encounters $D[a_i]$ which then must fire, since the *remote* array D[b] fires in about half the trials. Thus (1) even though [R] spans $[a_i]$, (2) $[a_i]$ is a viable position identity option for the QO, and (3) $D[a_i]$ is probing for a QO in $[a_i]$, nevertheless, the position identity option $[a_i]$ is not always chosen, and $D[a_i]$ does not always fire.

To explain this mystery is, of course, to resolve Dilemma$\underline{2}$. But a resolution requires figuring out not only how the QO is organized and modified, but also how the QO interacts with those component objects that constitute the detector and also how these components together compose the detector. Our concern here is the first task, so let us proceed in terms of "detectors," even though these are reducible composite systems. Caution will be needed to avoid ascribing a formal structural equivalence in physical theory between extended but irreducible-in-public-space entities (like QO's) and extended but reducible-in-public-space structures (like detectors, splitters, etc., and Schrödinger cats).

During detection, the QO cannot continue to maintain a wide range of identity options. If [R] does not overlap $[a_i]$, then $D[a_i]$ stays untriggered. This is the case well before the QO reaches the vicinity of the detector and is in accord with the usual intuitions.

If [R] does overlap $[a_i]$ *and* the QO's structure includes the position identity option $[a_i]$, then $D[a_i]$ *may or may not* fire. If $D[a_i]$ does fire, then the bloated QO has collapsed into $[a_i]$, and all position identity options other than $[a_i]$ have been eliminated from the QO's identity structure. Again, no problem for the usual intuitions. But if $D[a_i]$ does not fire, even though the QO has reached $[a_i]$, then the identity option $[a_i]$ has been closed in the QO's identity structure, leaving active only the remaining options. [R] reduces to exclude $[a_i]$. This is not in tune with usual intuitions. $D[a_i]$ does not fire, not because the extended QO has not reached it, but because the QO's structure is such that the QO need not collapse into $[a_i]$, even though it is being probed in $[a_i]$. How this happens is mysterious, but the crucial point is that it does happen. That it can happen stems from the QO's private, superfast rate of self-coordination compared to the rate of any public probe.

In summary, the probed QO undergoes a choosing process in accord with its set of identity options and the particular subset of this set that is being probed. This decision process either leaves actual only the probed subset of identity options and eliminates the unprobed subset, or eliminates the probed subset and leaves actual the unprobed subset. The reduction of [R] is consistent with the choice. The effect on the QO of a shifter or a splitter can also be expressed in terms of a selection process over the QO's set of identity options.

This conceptual picture of the QO as a unified, extended, *choosing* object and of the detector as a composite object catalyzing a decision process in the QO treats the QO and detector inequivalently. The QO is always affected by the detector, whereas the detector does not always appear to be affected by the QO. But at the level where the laboratory devices are described in gross functional terms and not in terms of the constituent structures, an inequivalent treatment of the QO and the devices is entirely appropriate. On a more fundamental level this asymmetry in describing interactions should vanish.

A key feature of the experiments is the inhomogeneous distribution of counts within an array. Consider the Fig. 2 experiment (emitter$\underline{2}$ on): only D[a] fires. Either each undetected QO develops all the position identity options $[a_1]$, $[a_2]$, …, and they are inequivalent in a standard way within the identity structure of each QO, such standard-to-each-QO inequivalence yielding the inhomogeneous count distribution, or each undetected QO develops only a subset of the identity options $[a_1]$, $[a_2]$, . . ., and the variation of this subset over many QO's is the source of the inhomogeneous count distribution. The difference boils down to whether all the undetected QO's from the same emitter are structurally identical (i.e., a pure ensemble) or whether there is a variation in structure, that is, a mixture of "somewhat different" QO's. Let us adopt the first scenario, whereby all the QO's are basically the same. The standard inequivalence between each QO's identity options may then be represented by a time-dependent "weight factor" for each identity option.

It is tempting to relate the normalized count distribution over the detectors with the distribution of weight factors of the position identity options actual in the identity structure of the QO just before detection. If D[b] practically never fires, the weight factors for the identity options $[b_1]$, $[b_2]$, . . ., were practically nil. The weight factor of a position identity option $[a_i]$ reflects the chance whether, in a probe by $D[a_i]$, the identity option $[a_i]$ will be exclusively chosen, eliminating the other position identity options developed before the probe.

7. SOME INTERESTING EXPERIMENTS

What can be examined, without a detailed physical theory, is the relation between [R] and the QO's set of position identity options having nonvanishing weight factors. Suppose $D[b_j]$ practically never fires or fires much less frequently than at the peak count. For that configuration, either the QO did not develop a position identity option whose domain is bounded by $[b_j]$, or if it did, the weight factor of this identity option remained very small. Let us call such an identity option "not viable." The QO's remaining "viable" identity options have weight factors big enough so that a probe for a QO with one of the "viable" identity options will count with a non-negligible frequency.

Suppose the large [R] includes a small subregion [r], the size of a minidetector. Must [r] be a viable position identity option of the QO? Does every subset of [R] bound the domain of a viable position identity option of the QO? To show the answer is "no!," let us go back to the lab.

In the Fig. 6 experiment where only D[a] fires, leave in place all the equipment except for detectors. Carefully add two shifters and place the detectors as in Fig. 9.1. Now, only D[b] fires. One might think that the output QO to splitter$\underline{2}$ traverses only shifter$\underline{2}$ and not shifter$\underline{2}'$; that is, the output QO is equivalent to a QO that would be produced by replacing all the equipment between the emitter and splitter$\underline{2}$ by a QO emitter placed at the original position of splitter$\underline{2}$ and pointing in the input direction of shifter$\underline{2}$. The extent [R] of such a QO would not include $[a_1]$, $[a_2]$, ... But this cannot be right, since a third splitter can be added, as in Fig. 9.2, to achieve an interference result. Thus the output QO of splitter$\underline{2}$ in both Figs. 9.1 and 9.2 traverses *both* shifter$\underline{2}$ *and* shifter$\underline{2}'$. The output QO in the Fig. 9.1 experiment extends to $[a_1]$, $[a_2]$, . . ., as well as $[b_1]$, $[b_2]$, . . .; yet, the position identity options $[a_1]$, $[a_2]$ remain not viable. Hence the detector-catalyzed choosing process over the QO's identity options will reduce [R] only into D[b].

In the Fig. 9.2 experiment, splitter$\underline{3}$ affects the QO's identity structure, so that when [R] reaches [a] and [b], there is significant variation in the weight factors of the position identity options over these regions. The detectors stimulate a reductive choosing over the QO's identity options in accord with the weight factors actual during the probe. [R] shrinks and eventually one of the detectors fires.

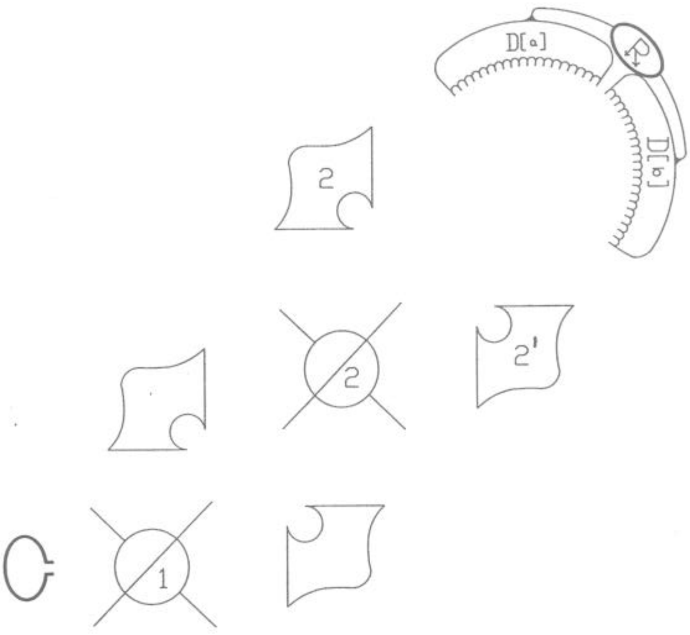

Figure 9.1. Extreme interference; only D[b] fires.

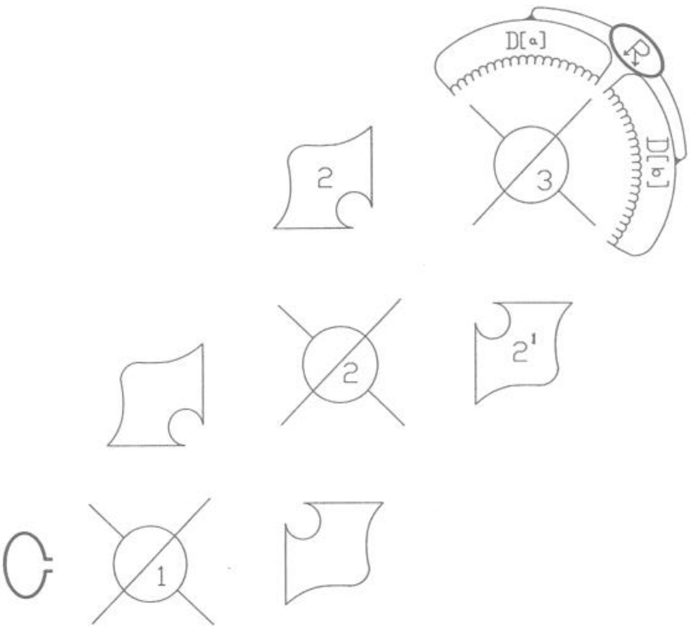

Figure 9.2. Three-splitters; interference pattern over D[a] and D[b].

The possible mismatch, over the time of probe, between the QO's public extent [R] and the domain of the QO's viable position identity options is an essential feature of interference phenomena. It indicates internal-to-the-QO organization. This means that the QO's extent includes places where the QO practically cannot be found or that, even if a QO is almost never found in a particular place, the QO may still span that place. This wierd property is absent in usual objects whose every subregion encloses a separately detectable component.

These inferences do not rest on the peculiar, extreme-interference example. To show this, consider the Fig. 6 experiment with complementary interference patterns over D[a] and D[b]. Suppose the minidetectors are small enough that the region of an interference minimum near the center of the count distribution is broader than a minidetector. Suppose there is practically no count at the center of D[b], say, D$[b_j]$ does not fire (or fires with a low frequency). Suppose there is practically no count at an interference minimum near the center of D[a], say, D$[a_i]$ does not fire. Now, replace D[a] and D[b] by a barrier (as in Fig. 10), impervious except for two holes at $[a_i]$ and $[b_j]$. The width of each hole is not bigger than a minidetector.

Does the QO traverse the two-holed surface? It is practically not detected at either $[a_i]$ or $[b_j]$ and the only routes through the surface are via $[a_i]$ and $[b_j]$. Were the QO a usual object, one could argue that if the only way through the barrier is via $[a_i]$ and/or $[b_j]$ and neither the object nor part of it is found at $[a_i]$ or $[b_j]$, then the object cannot get through the barrier. But the extended QO, unlike usual objects, has no public parts. Nondetection in $[a_i]$ or $[b_j]$ does not mean QO absence there. [R] spreads to $[a_i]$ and $[b_j]$, yet these regions are not viable position identity options for the QO. Now look for the QO with array D[c] beyond the barrier. Since D[c] *does* fire (at a much greater rate than that of either D$[a_i]$ or D$[b_j]$ in the Fig. 6 experiment), this confirms that even if the QO is practically not detected in a public subregion, it may still encompass that subregion. Not every subset of [R] bounds the domain of a viable position identity option, the subset may correspond to nonviable identity options.

The foregoing experiment serves as a prototype for other interference devices. For example, consider the double-aperture device of Fig. 11.1, where an interference pattern develops over the detector surface D[b]. Suppose minidetectors D$[b_i]$ and D$[b_j]$ each lie within a separate region of negative interference (dark fringe) and practically do not fire. Replace D[b] with a barrier surface having apertures only at $[b_i]$ and $[b_j]$, as in Fig. 11.2. The simplest way is just to remove the minidetectors D$[b_i]$ and D$[b_j]$ and turn off the remaining detectors in D[b]. Look for QO's at the detector surface D[c] behind the double-double aperture. Since QO's are detected by D[c] at a rate significantly greater than the almost null rate at D$[b_i]$ and D$[b_j]$, the QO actually traverses places where it is not trappable.

Our qualitative scenario explains what is happening in the experiment. The emitted QO publicly expands yet retains structural unity by virtue of superluminal private space processes. The QO develops a wide range of position identity options. Take the first barrier as a QO-absorbing detector array except for two apertures. The output QO to this barrier may expand initially through the two holes (which are viable position identity options for the QO). One "thing," the QO, goes through two holes and stays one "thing." The unifying connection is private but nonetheless real. [R] continues expanding, and there is significant variation in the weight factors of the identity options. The two apertures in the second surface remain nonviable position identity options (as is inferred from the experiment of Fig. 11.1), even though [R] covers these regions. Now, (1) if [R] can expand to include region [r′] beyond the holes, and (2) if [r′] is a viable position identity option – all this, *before* the completion of any probe to localize the QO – then the detection process can catalyze the QO's collapse into [r′], and the QO may be detected beyond the second surface.

Needless to say, this you-cannot-always-see-the-thing-but-it-is-really-there experiment could be improved by replacing the first two-holed surface by an interference device that yields very wide and deep interference minima on the second surface.

The common intuition based on experience with usual objects is, as we have seen, a poor guide for forming expectations about the QO; so, until there has been built up new, well-founded intuitions, we should be wary of summarily dismissing "obvious" questions and carefully examine seemingly picayunish issues. For example, if the second surface in the double-double aperture experiment is an array D[b] with two apertures formed by removing minidetectors centered on two interference minima, is the count rate at D[c] different when the remaining detectors in D[b] are left on than when these detectors are left off? Is there an appropriate choice for the shape and position of D[b] so that, when it catalyzes the collapse of [R], the QO has no viable position identity options whose domain is beyond [b], in which case the QO would be detected within D[b] and not within D[c]? Or, is the rate of expansion of [R] so fast that, regardless of whether D[b] is active and regardless of D[b]'s layout, the QO always manages to develop viable position identity options whose domain lies beyond the holes, in which case the QO is detected in D[b] *or* in D[c].

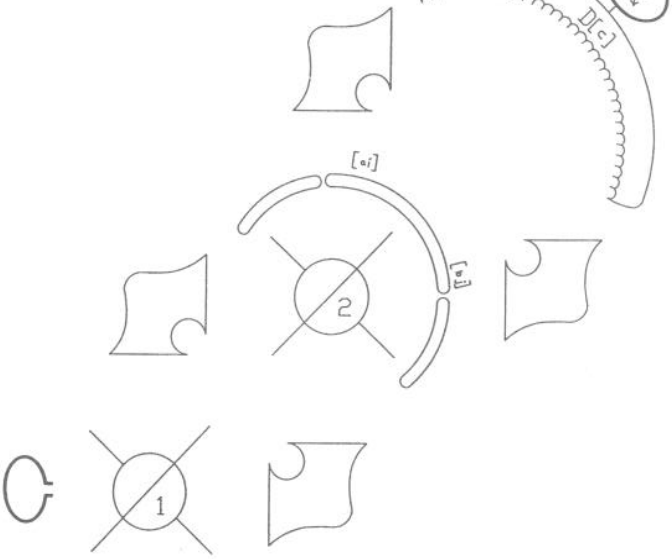

Figure 10. A surface with two holes, $[a_i]$ and $[b_j]$, surrounds the output of two-splitter interference. There are no counts for detectors put into the holes. Yet, with the holes open, D[c] fires.

8. SO WHAT!

There already is a successful set of rules – QM – for predicting experimental results for detected QO's (so-and-so-ons). In developing a conceptual model of the QO, the approach here has been to avoid conflict with QM and implicitly to adopt QM as a constraining guide. This strategy required not barricading ourselves into *a priori*, overly restrictive conceptions of what physical structure *must* be and also being very circumspect in interpreting what QM represents.

Suppose QM is viewed as a strictly pragmatic calculational scheme for predicting (usually in statistical terms) certain experimental outcomes, without regard to actual undetected structure or processes. As an abstract recipe for dealing with certain of our shared perceptions, QM is eminently useful and trustworthy. But lacking an explicit OR picture, QM ignores questions of actual public presence before detection, an essential structural feature of an object that "is." The quantum state vector is just a useful mental artifice; it does not, in the rules of QM, represent actual, independent-of-people structure. Of course, one can, without regard to any physical theory, still retain a murky, broad belief in the existence of actual undetected quantum structure. But in QM there is no manifestation of, or necessity for, this belief; that is, the belief is decoupled from the physical theory. One can understand those who, in light of how well QM works, find unnecessary the notion of actual quantum structures. A succint expression of this position is Bohr's statement: "There is no quantum world, there is only an abstract quantum physical description. It is wrong to think the task of physics is to find out how the world is, physics concerns what we can say about nature."(5),4

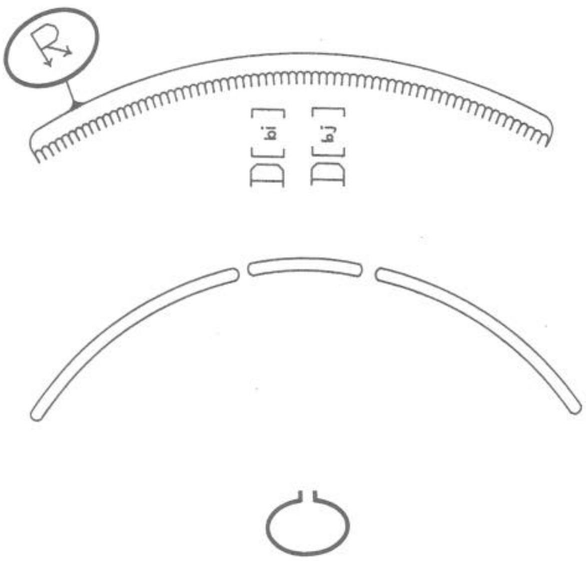

Figure 11.1. A stream of QO's is directed toward a two-holed surface. D[b_i] and D[b_j] do not fire, because they are at interference minima.

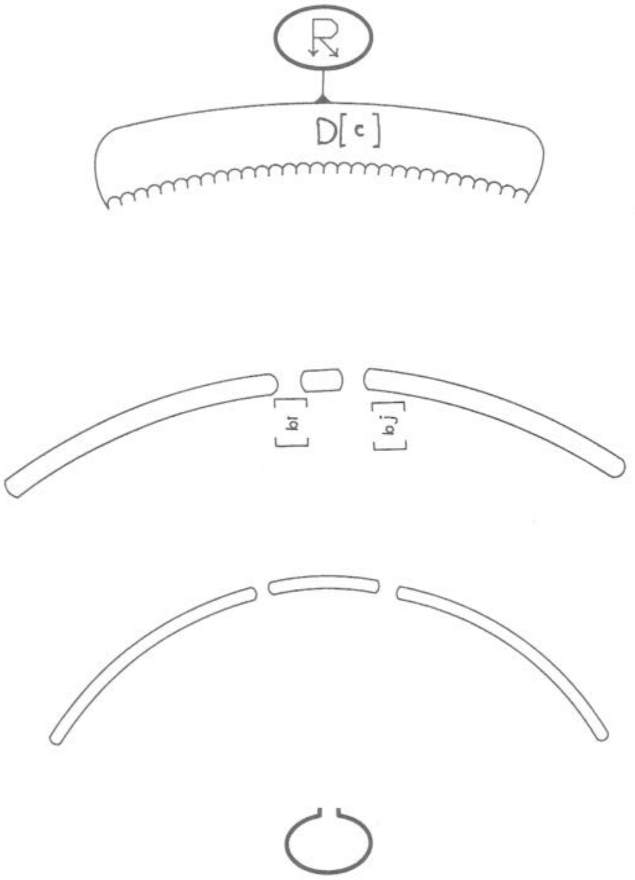

Figure 11.2. Array D[b] of Fig. 11.1 is replaced by a surface with holes at [b_i] and [b_j]. Array D[c] fires.

The OR approach, on the other hand, suggests that if the undetected QO is a real, independent entity, then cognitive prescriptions for predicting experimental results for detected QO's stem from actual structures or processes. Physical theory is grounded on the nature of OR, even though the connection to OR may remain implicit if the theory is formulated only as a convenient calculating algorithm. A widespread willingness to settle for a "scientific black box" approach – if a theory, like QM, works well in predictions for detected objects, then there is no point in digging deeper to understand undetected quantum structure – indicates that progress toward an explicit OR-type theory for physical structure may be slow.

To advocate a structural reinterpretation of QM wherein the descriptive reference is shifted to quantum objects is easier said than done. An initial step in this direction is to associate the state vector of QM with the QO's developing set of identity options and their weight factors, thereby tying QM to a constraining aspect of the QO's structure. But even the identity option language is just an implicit formulation for dealing indirectly with private domain QO structure and is not an explicit structural description. Thus mere compatibility with QM is, in the long run, not enough; the issue is not one of "just" repackaging QM according to a different taste, style or semantics. An OR interpretation of QM, which is entirely equivalent in consequences to who-cares-about-OR QM, offers no substantial response to the *pro status quo* challenge: What does it add? What difference does it make? The goal of an OR approach is an explicitly structural theory of what is happening that retains all the successes of QM and yet goes beyond it to account for all physical processes, including those internal private world processes that have physical consequences in the public domain.

The conceptual picture introduced here is very useful in ferreting out possible obscure phenomena for testing QM against OR considerations. This is because a structural picture of what is happening may elucidate critical design features that are obscured in a detailed formalism not geared directly to what is really going on before detection. Let me now point out how an OR-type theory could part ways with QM yet retain QM's successes.

In QM a pure state evolves by a unitary transformation. In a basis of the eigenstates of the quantum operator corresponding to some observable, the state vector of a closed system that is initially a superposition of eigenstates continues as a superposition of the eigenstates. Each eigenstate has a corresponding eigenvalue representing a possible outcome of measuring the observable. Now suppose a detector is introduced to "measure" the observable. For any given trial, only one value of the observable is finally registered. But one value of the observable corresponds to just one eigenstate (ignoring, for simplicity, possible degeneracy). So how is the quantum "jump" from a superposition of eigenstates to a definite eigenstate accomplished? Or, in terms of many trials, how is a pure ensemble that superposes eigenstates before measurement converted into a statistical mixture of definite eigenstates?(6)

With a pragmatic, operational interpretation of QM there is no such "measurement" problem, since the state vector is not regarded as specifying a real structure, nor does state reduction represent an actual physical process. The QM formalism is just a calculational tool for determining probability amplitudes and from these, the probability of a detected event. In Feynman's words: "Keeping this principle in mind should help the student avoid being confused by things such as 'reduction of a wave packet' and similar magic."(7)

On the other hand, in the conceptual picture presented here, the reduction of the bloated QO *does* represent an actual physical process – a superluminal choosing process grounded in structural transformations over a private space. Suppose the quantum mechanical state vector of the system corresponds to the QO's set of identity options. The detector-catalyzed reductive choosing over the QO's identity options then corresponds to the usual state vector reduction of QM. But if underlying the state vector are private space processes unifying the QO, there may be circumstances prompting state reduction *without stimulation by external detectors*. Such a spontaneous reduction would conflict with the "once a pure superposition state, always a pure superposition state" QM rule for isolated systems.

Suppose there are no detectors around. How big can [R] get? Can an undetected QO spread over huge public regions or even the entire public space without internal instability? Since [R] bounds the QO's position identity options, how wide a range of such options can be coherently maintained by one QO? Since all physical processes take time, the private, unifying process over the QO's structure is not infinitely fast (no physical process occurs instantly) even if it is superluminal. Thus, if [R] gets big enough, the isolated, expanding QO may become unable to maintain structural integrity. Even with internal coordination at a superluminal rate, the QO may reach an organizational coherence limit, a critical limiting size beyond which it cannot stably continue to expand as one thing. In this case the QO may, *without a catalyzing detector*, undergo a physical process equivalent to reductive choosing over the set of position identity options. This choosing process need not lead to drastic collapse into a detector-size domain; the reduction need only offset the expansion to keep [R] bounded by the critical limiting size. If so, then in the Fig. 6 experiment, the interference pattern should begin to break down and become unattainable for sufficiently large separations between the devices. But these distances may be very large.

If the extended QO has a temporal stability limit, then to reveal it consider the Fig. 6 setup where the distance between splitter_ and each shifter is equal and as large as possible, yet yielding clear interference patterns over D[a] and D[b]. Now, just beyond each output direction of splitter_ and well before the shifters, introduce a very long delayer. *If* each delayer can suddenly be converted into a closed delayer-loop after the QO has extended into it but well before the QO reaches a shifter, that is, if one QO can be put into "storage" in two separate regions over the same time, then wait long enough (more than the QO's temporal stability limit) to open the delayer-loops into the shifters. The undetected QO is trapped within two distinct delayer-loops, but remains one object connected together privately. If before release it spontaneously decays into one storage loop, there should be no interference pattern over D[a] and D[b].

But interference breakdown in spread-out experiments could be attributed to external-to-the-QO interactions and not to internal-to-the-QO processes allowing spontaneous reduction. For example, does a closed loop constitute a "detector" which stimulates reduction? Or does the collective influence of the rest of the universe (gravity) eventually prompt reduction for the expanding QO? The challenge is to find a convincing example of spontaneous reduction.

The EPR experiment(1) in the Bohm spin-correlation version(8) done over very large distances may well offer a test for the spontaneous conversion of a superposition pure state into a statistical mixture, contrary to the canons of QM.(9) To see this, let us apply the QO picture to the zero-spin system whose detected decay products are two spin-½ particles β_1 and β_2.

The spin-singlet QO expands as a single entity with a developing set of identity options. Each identity option is expressed in terms of public attributes of a pair of β objects; but this does not mean the singlet-QO consists of two objects as is often tacitly assumed. In the state vector formalism of QM for keeping track of identity options, it is not possible to express the singlet state as a product of two factors, one associated with β_1 and the other with β_2. Thus the singlet QO is *not* a composite structure constituted from two β's; it is one, irreducible-in-public-space thing. Even though its public extent spans two distinct regions growing farther apart, the singlet QO does not have separate component parts in each region, but is one object, structurally unified by a private connection.

A β detector catalyzes a structural transformation within the QO – a choosing process over the set of identity options that reduces the singlet QO into *two* β's. The correlations between β's follow from the identity structure (as summarized by the state vector) just prior to the probe. According to QM bereft of OR considerations, there is no spatial or temporal limit to the applicability of a spin-singlet state vector prior to detection. But with an OR picture, there may be a structural stability limit for the singlet QO beyond a critical extent and *before* any probe, in which case there could occur spontaneous departure from the pure singlet-state identity structure. Thus the resounding successes of usual QM over moderate distances would be retained, and the possible deviations from usual QM would develop only in exceptional circumstances (over large distances).

What sort of singlet breakdown can we expect? If the singlet QO necessarily reduces spontaneously into a pair of spin-anticorrelated β-QO's (with no preferred direction for the common spin axis of the pair), this is the Bohm-Aharonov(10) scenario. This proposal gives a probability of ⅔ for *measured* spin anticorrelation along a given spin axis (as opposed to unit probability for the pure singlet) and satisfies the Bell inequality(11) (which the pure singlet violates). According to our QO picture, this reduction scenario is relevant *only for very large distances* and not for the range where spontaneous breakdown of the singlet may initially occur.

For those distances where spontaneous reduction first becomes possible but is not yet necessary, the singlet QO would, in most trials, continue in the singlet state until detection and, only in some trials, would collapse spontaneously – in advance of detection – into a spin-anticorrelated pair. For this initial reduction scenario the probability for measured spin anticorrelation along a given spin direction is less than, but close to, unity, and the Bell inequality stays violated. The identical consequences result from another seemingly different scenario for spontaneous reduction: the singlet QO transforms into an object, an "eroded singlet QO," whose identity structure superimposes the singlet state *and* the spin-anticorrelated pair state (with the singlet factor initially dominating the superposition).

Both these proposals for initial singlet breakdown allow a very gentle, slight departure from the predictions of usual QM and interpolate between results of the pure singlet and the Bohm-Aharonov proposal. An essential feature is the deviation, for sufficiently large separations between the β detectors, from strict anticorrelation between the *measured* components (along a given spin direction) of the spin angular momenta of the detected β's.

As the detector separation increases, the singlet factor becomes less significant, and the anticorrelated pair factor starts to dominate, Bell's inequality becomes saturated and is eventually satisfied.

Afterword

Efforts to cope pragmatically with the results of our perceptions should be complemented by attempts to figure out what is actually happening to physical structures. "Physics is an attempt to grasp reality as it is thought independently of its being observed."(3)

There are many puzzling, unanswered questions to what is really going on. One would hope that every physical process, even private processes, has some implications or consequences that we can investigate in the shared public world.

Acknowledgment

I am grateful to the Jerusalem College of Technology for a sabbatical leave and to McMaster University for its hospitality. I am especially grateful to my wife and children and to my family abroad for providing the conditions that allowed the development of this work.

Received 16 May 1990.

Résumé

Les prototypes des phénomènes quantiques pour les systèmes libres sont analysés à partir d'une perspective d'une "réalité objective". Les modèles ordinaires pour un objet quantique (OQ) sont montrés d'être inacceptables. On propose une nouvelle illustration conceptual du OQ. Le OQ non détecté est une structure physique étendue, qui n'a pas des parts publiques, quoique elle maintient une intégrité structurelle extrême en vertu des processus superluminaux dans un espace unifiant privé. Aucune sonde publique est plus vite que les connexions privées unifiantes le OQ. La structure de l'espace privé est caractérisé par un group en évolution de options d'identités, chacune liée à un attribut publique. Les sondes de OQ stimulent un processus de décision sur le group des options d'identités. Une experience de double double-ouverture montre que le OQ traverse des endroits où il ne peut pas être piégé. On adresse la relation entre la mécanique quantique et le OQ. On propose la réduction spontanée (c.-à-d. pas stimulé par les sondes) du vecteur d'état à des grandes distances. Le modèle du OQ permet un écart modéré des prédictions de la mécanique quantique dans des situations exceptionnelles qui n'ont pas encore été étudiées expérimentalement.

Endnote

[1] This paper is dedicated to the memory of Jake Freeman, 5 Tevet 5711 – 5 Tevet 5749.

[2] A prototype of a Mach-Zender interferometer.

[3] It is tempting to associate the two kinds of electric charges with the two possibilities for private-domain structure, extending either outside the public surface or inside the public surface.

[4] Presumably the reference to "nature" means "human perceptions" or "detected/observed phenomena" and not an independent-of-people world.

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