Quantum Realism and Haecceity

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haec.ce.ity [hek-see-etee] *noun*

The essential property that makes an individual uniquely that individual – *Encarta*

The quality implied in the use of *this*, as *this man*; thisness; hereness and nowness; that quality or mode of being in virtue of which a thing is or becomes a definite individual; individuality - *OED*

1. INTRODUCTION

Non-relativistic quantum mechanics is incompatible with our everyday or ‘classical’ intuitions about realism, not only at the microscopic level but also at the macroscopic level. The latter point is highlighted by the ‘cat paradox’ presented by Schrödinger. Since our observations are always made at the macroscopic level — even when applying the formalism to the microscopic level — the failure of classical realism at the macroscopic level is actually more fundamental and crucial.

This paper is part of a larger research program aimed at applying non-relativistic quantum theory to the macroscopic world, but *without* requiring its description to reduce to classical physics. Such an application would have to be independent of the current, microscopic statistical quantum mechanics (SQM), which presupposes the ‘classicality’ of the macroscopic world. Therefore, the proposed macroscopic quantum mechanics (MQM) should not be expected to reproduce the probabilistic predictions of SQM. This point marks a fundamental departure from the route of decoherence. What then will be relationship between the proposed MQM and SQM? I shall return to this question in the concluding section, after developing some necessary ideas.

The present paper represents only a small part of the programme to develop a MQM independent of current SQM. It argues for a new way of thinking about the failure of classical thinking within quantum theory. I propose that the essential idea that fails in quantum theory is the ‘classical’ notion of haecceity, which pervades our everyday thinking concerning macroscopic objects. A fully consistent quantum theory requires an alternative, ‘quantum’ notion of haecceity. I examine the famous cat paradox from this standpoint, and argue that the paradox can be resolved if we allow macroscopic measuring devices to enter observable states compatible with superposition *simultaneously* and *in addition to* classically determinate states. I then point out that everyday thinking already permits two ways of identifying real-world macroscopic entities: as generic OBJECTS and as KINDS. The main idea of this paper is that an alternative physics based on a quantum notion of haecceity pertaining to scientific KINDS would explicitly allow for dual states in macroscopic devices, just as the objects of our experience can belong to several kinds simultaneously. I conclude by outlining my future programme to develop these ideas toward macroscopic quantum mechanics.

2. HAECCEITY AND QUANTUM THEORY

In everyday thinking, we distinguish between macroscopic objects easily enough. When two objects are very similar, we naturally fall back on ostensive definitions: ‘this object’ and ‘that object’. We may also mentally or physically label them: ‘object 1’ and ‘object 2’.

Even if there were only *one* object in our vicinity, we could still refer to it as ‘this’ object. Haecceity is supposed to account for the ‘thisness’ or individuality of any *single object*.

But what is the origin of this haecceity? Metaphysically, we might presume that given a detailed enough description, each and every object will be found to have some *unique physical trait*. Given two identical-looking coins, for example, we expect that close examination will reveal some differences: one is slightly thicker, or has a scratch.

However, it is conceivable that the two coins are physically absolutely identical. We would still regard them as distinct *individuals* in this case; the coins have haecceity.

What is our physical basis for asserting the haecceity of two *physically identical* objects?

In the ‘classical’ range of everyday thinking—so named because it has largely been taken over in classical physics—each ordinary, macroscopic object is taken to be ‘rigid’ and impenetrable, meaning that at any given instant it occupies a unique spatial location that it cannot share with any other macroscopic object. Classical thinking thus endows each macroscopic object with a unique trajectory in space and time or a unque ‘world-line’ space and time.

According to this classical view, the haecceity of macroscopic objects stems from their unique spatiotemporal locations. Classical thinking relies on the belief that any macroscopic object exists at a definite location in space at every instant, independent of our acts of observation.

Quantum theory also encounters the problem of individuating 'indistinguishable' objects. Quantum mechanical experiments are always performed using macroscopic objects (such as sources, detectors and in-between devices such as Stern-Gerlach magnets and beam splitters), even when the experiments are about the behavior of microscopic objects. For this reason, the 'quantum state' prepared by the researchers must be common to all particles emitted. The macroscopic 'sources' used in these experiments generate an ensemble of particles in *identical quantum states*.

Nevertheless, physicists do treat such quantum particles as individuals on empirical grounds. In a typical experiment, for example, we might say 'this particle caused this click'. Yet quantum particles cannot generally be said to have a definite ontological position independent of the actual measurement. Thus, classical haecceity may not be a fully appropriate component of quantum theory. If so, it would clearly be advantageous to have a non-classical notion of haecceity on hand to account for observable quantum individuality.

It is important to note that classical haecceity fails for *macroscopic* objects as much as for microscopic quantum particles within the present quantum theory. One can easily devise situations in the standard interpretation of quantum theory where a macroscopic measuring device M, by interacting with a quantum particle in a state of superposition, cannot be said to have a definite location in space and time independent of acts of observation.

This conclusion not only violates commonsense notions about macroscopic reality, but also contradicts one of the assumptions underlying applications of quantum theory to the microscopic regime. As I shall argue in the following section, our present quantum mechanical praxis *assumes* that macroscopic measuring devices will have definite locations *at all times*, whether or not we observe them. Schrödinger's so-called 'cat paradox' (which does not really require a cat) actually highlights this contradiction within present applications and interpretations of quantum theory.

If the goal of realism is to fit quantum theory to commonsense intuitions (which always operate at the macroscopic level), then it makes sense to associate the failure of quantum realism with the existence of the above contradiction at the level of macroscopic objects. If so, the failure of classical realism at the *macroscopic* level is of greater consequence and more germane to the issue of quantum realism than the failure of classical realism at the atomic level.

The main goal of this paper is to show that what fails in quantum theory at the macroscopic level is not even classical realism *per se* but classical haecceity in particular and that too only partially. This view can explain why the current quantum mechanical praxis has remained ontologically sterile, even as it achieves tremendous practical success. The following sections will fully justify these statements. At the end of the paper, I will describe how the notion of KINDS from everyday thinking can provide an alternative source of haecceity appropriate for quantum observation on both macroscopic and microscopic scales.

3. QUANTUM THEORY AND MACROSCOPIC REALITY

Consider the standard two-slit experiment. To observe which slit an individual electron passes through, two detectors D1 and D2 are placed close to the slits. To serve their intended purpose, D1 and D2 must have classically definite locations (such as a needle pointing to a definite location, or a switch definitely having clicked) *independent of* and *prior to* the observation. This assumption is basic to our very use of macroscopic objects as devices that can carry out a position measurement. Let us call this assumption **A**.

Assumption **A** is essential to Born's rule, since position is the most basic measurement. Any other physical property of a quantum particle (momentum, angular momentum, spin, etc.) is ultimately observed by recording the *localized position* of some macroscopic measuring device **M**. Thus, we are justified in saying that **M** must have a definite location independent of observation if Born's statistical rule is to work.

Let us now consider a quantum particle 'going through' the two-slit screen in a state of superposition S with respect to the position observable. The state S can be expressed in the associated basis as

$$S = \sum_{i=1}^{2} c_i \psi_i$$

where the ψ_i are position eigenstates. In the pedagogical formalism, these are delta functions describing a 100% probability that the electron will be found at a particular position (the top slit or the bottom slit) when the detectors D1 and D2 are placed just in front of the screen.

However, assuming 100% efficiency, only one of the detectors will enter the definite classical state of having clicked. The probability that detector *i* will click in any given observation is c_i^2. If the electron beam is aimed halfway between the slits, both probabilities will be ½.

If the detector in front of the top slit has clicked, the electron is said to have entered the ψ_1 eigenstate *as per our current realistic interpretation of the observation experience*: to wit, the idea that our observation qua sense experience (the audible click) reveals a definite location where the detection event has taken place. Similarly, if the detector at the bottom slit has clicked then the electron is said to have entered the ψ_2 eigenstate.

But the idea that our observation experiences reveal a pre-existing, definite location for macroscopic objects is just the assumption of classical haecceity. One problem that arises from using classical haecceity within quantum theory to interpret the observed states of macroscopic measuring devices is that the superposed quantum state is understood as a simultaneous combination of two possible locations. But this is a physical impossibility to our everyday thinking. Thus enters the paradox: the prepared superposed state is *not* directly observable within the classical interpretation, either for the particle or for the measurement device, yet we are somehow capable of creating this state by manipulating macroscopic equipment.

But does the fact that we associate an individual observation with a specific eigenstate necessarily mean that the superposed state S ‘went away’ at the point of measurement? Most physicists would agree with this thinking, which forms the basis of the projection postulate.

Such thinking actually contradicts the assumption **A**. I see Schrödinger’s ‘paradox’ as calling attention to this specific problem. It is possible to write the joint quantum state of the (electron + detector) system *after* the two have interacted as follows:

$$|J> = {}^{1}/_{\sqrt{2}}\ [|\,\Psi_1 > |u> \ +|\,\Psi_2 > |d>]$$

Here |u> and |d> are macroscopic quantum states where the top and bottom detectors have clicked respectively. Only one of these detection events will occur when an observation is carried out, and both detectors will be in a definite state (of having clicked or not clicked) after the observation.

If the joint state |J> is taken to be a realistic description of the situation *prior to observation,* then neither detector begins in a definite state (of having clicked or not clicked). Most physicists would agree with this viewpoint too.

However, there are two problems with this conclusion:

(i) It means that our acts of observation can radically alter observed reality, even at the macroscopic level.

(ii) It contradicts our assumption **A**, that definite macroscopic locations for macroscopic objects prior to observation are necessary for making meaningful measurements.

The first conclusion is too much of a stretch, given our practical experiences of life, while the second appears to invalidate practical applications of quantum theory to the experienced world using Born's rule. For if the detectors do *not* have a determinate location prior to observation, the normal practice of applying quantum theory only to the particle state and using macroscopic detectors only to infer the position of the particle cannot be carried out.

Of course, textbooks do not apply quantum mechanics to the macroscopic realm. The contradiction just described arises only when we *extend* this interpretation to the macroscopic realm. It is not internal to statistical, microscopic quantum mechanics.

Nevertheless, the said contradiction strongly indicates that if we wish to apply the quantum formalism to the macroscopic realm, we must do so in a manner that is independent of and yet compatible with the current statistical, microscopic quantum mechanics.

Such an approach is conceivable *if a superposed state and its component eigenstates can coexist in a quantum system, in a complementary manner* Such a possibility would allow us to retain the pragmatic success (and internal consistency) of current quantum mechanics at the microscopic level, while at the same time striking out to develop a complementary, quantum-compatible treatment of the macroscopic world.

4. THE DISTINCTION BETWEEN ONTOLOGICAL STATES AND EIGENSTATES

Physicist Sir Denys Wilkinson once wrote, ‘The fact that when nuclei are struck violently together nucleons come out does not prove that nucleons were inside in the first place—barks come out of dogs but that does not prove that dogs are made of barks.’ [Wilkinson, 1978,144]

Wilkinson’s statement can be adapted to discuss the relationship between an ontological quantum state prepared in an experiment and the eigenstates correlated with classical states of M. Although it is true that such ‘classical’ eigenstates in some sense ‘come out’ of the prepared ontological state, it does not necessarily follow that the ontological state is ‘made up of’ these classically interpreted eigenstates. The following analogy will clarify this point.

Let us say we choose to describe a dog in terms of two states that we can observe, namely ‘barking’ and ‘not barking’. Clearly the ontological real state of being a dog, call it the [dog] state, is independent of these two *observable states*. That is to say, although we connect the act of barking to the dog, the ontological state of *being* a dog has nothing to do with its barking. Even though every observation we make upon the ontological [dog] state will always find the dog to be in a barking’ or ‘not barking’ state, we can state confidently that the dog will *continue* to remain in its distinct ontological [dog] state in either case.

Of course, we could express the ontological [dog] state in terms of some other observable property (such as being inside or outside the house). This process is equivalent to expressing a given ontological quantum state as a superposition of eigenstates of some other basis. While it is true that a lot of information about the dog can be collected by defining and observing various observable states, I take it as intuitively obvious that the nature of the ontological [dog] state, belonging to the external world, cannot itself be clarified from such information. That is, the [dog] state is entirely distinct from any expression as a superposition of observable states, and exists distinctly and independently even at the point of an actual observation.

In other words, we would do well not to conflate the ontological state and its expression as a superposition of ‘classical’ eigenstates.[1] Even in the current formalism, although the ‘superposed state’ is explicitly made up of ‘classical’ eigenstates, the ‘ontological state’ exists independent of any basis. The psi function can represent either—but treating the two as equivalent is a backward reconstruction based on our *observations* of the ontological state, nothing more. Relating the eigenstates to classically interpreted M states remains a valuable mathematical tool for (statistically) predicting observable states, which are related to but do not exhaust the ontological state. Making this distinction enables us to consider a radical new possibility: even though any observation of a quantum system corresponds to one of its classically conceived eigenstates, the ontological quantum state (*not* a 'superposition' of classically interpreted eigenstates) continues to apply and *coexists* with that eigenstate.

The parable of blind men reporting their perceptions of an elephant might help bring out the full force of the suggested approach. Because they describe their experiences using everyday words (pillar, broom, wall...) that are basically inappropriate, their individual descriptions cannot be combined to form a single, consistent picture of the ontological elephant. This much is easily seen. However, I am further proposing that their descriptions cannot be considered as being 'about the elephant,' *even at the point of observation*. Since the language is inappropriate, at best their descriptions only provide a *comparison* between their current observation experience and previous encounters with other objects. However, an alternate range of everyday language words such as legs, tail and belly would allow the blind men to mesh their individual observations into a unified ontological notion of the elephant.

Similarly, as long as we interpret macroscopic sense experiences corresponding to quantum mechanical observables using *fundamentally inappropriate* notions such as 'position', 'frequency' and 'momentum', we should not expect to arrive at a consistent picture of the ontological quantum object. These concepts are inappropriate because they rely on classical haecceity, which we have already shown does not apply generally to quantum mechanical systems. Furthermore, these properties should not be considered to describe the quantum object even at the point of observation. When we speak of wave and particle natures, we are simply comparing the present observation of a quantum system (whose nature we currently lack the terminology to describe) to our previous experiences of known objects (macroscopic particles and waves).

My long-term expectation is that by developing our intuition about observable yet alternative non-classical states of M, we will learn how the ontological quantum state can be a superposition of eigenstates in such a way that both can be related to individual observations. The rest of the paper will argue for this approach in greater detail. This approach is very much compatible with the essential non-classical features of the quantum formalism. For example, the eigenfunctions and their superposition are simultaneously solutions to Schrödinger's equation.

4.1 THE BOHR-EINSTEIN DEBATE REASSESSED

Given only a classically determinate view of M, we find an unusual situation: while there is an ontological quantum state represented by the quantum mechanical wave function independent of its expression as superposed states, there is as yet no observable property directly corresponding to that state. We are able to relate the classically determinate observations to eigenstates, but then we can never determine in a single experiment, in principle, the values of all observable properties. In classical thinking, such a move would be necessary to get at the ontological state. What can we make of this?

One response is that of Einstein: the superposed wave function provides an *incomplete* description of the system's ontological state.

Then there is the so-called 'standard' response, or the Copenhagen interpretation: the superposition state ψ does represent the underlying state, but we can only obtain partial knowledge of the system in any given experiment. Taken together, the complementary (i.e., mutually exclusive) observables exhaust whatever can be known about the object's ontological state. Bohr would have agreed with this statement, although his interpretation disagrees with the Copenhagen interpretation in many other respects [Gomatam, 2007].

As Bohr puts it, 'in quantum physics...evidence about atomic objects obtained by different experimental arrangements exhibit a novel kind of complementary relationship. Indeed, it must be recognized that such evidence, which appears contradictory when combination into a single picture is attempted, *exhausts all conceivable knowledge about the object*.' [Bohr, 1963, p. 4, italics mine].

This then is the essence of the Bohr-Einstein debate. Einstein held that the quantum mechanical description of the 'individual real situation' is incomplete. Bohr effectively *agreed* with Einstein on this point. In quantum theory, observations cannot be combined into a unified, measurement-independent picture of the object (as Einstein wanted). Even so, 'there could be no other way to deem a logically consistent mathematical formalism as inadequate than by demonstrating the departure of its consequences from experience or by proving that its predictions did not exhaust the possibilities of observation, and Einstein's argumentation could be directed to neither of those ends.' [Bohr, 1947, p. 229] Therefore, on the basis of quantum theory's empirical adequacy — statistical quantum theory has produced successful predictions in almost every conceivable experimental situation — Bohr insisted that we are forced to accept the limitations imposed by the theory on description, and reject any *prima facie* demand for a form of description based on preconceived notions. 'Only by a conscious resignation of our usual demands for visualization and causality was it possible to make Planck's discovery fruitful in explaining the properties of the elements on the basis of our knowledge of the building stones of atoms.' [Bohr, 1961, p. 108]

Bohr's stance is plausible enough. But why bring in the new concept of 'complementarity'? Does it add any explanatory content, other than giving a name to his capitulation? Bohr's response to this question is perhaps quite startling: in the context of quantum theory, the term signifies what I have elsewhere [Gomatam, 2007] called his pet 'inseparability' hypothesis. 'Far from restricting our effort to put questions to nature in the form of experiments, the notion of *complementarity* simply characterizes the answers we can receive by such inquiry, whenever the interaction between the measuring instruments and the objects forms an integral part of the phenomena.' [Bohr 1963, p. 4, underlining mine, italics in the original] The idea that measuring instruments and observed objects form an integral whole is the core of Bohr's personal interpretation of quantum theory.

To summarize, the Einstein-Bohr debate provides us with two stances: either the ψ state is ontologically incomplete (Einstein's), or it is ontologically complete but has limited descriptive content which cannot be improved upon (Bohr's).

4.2 GOING BEYOND BOHR AND EINSTEIN

This paper offers a *third* choice. I suggest that the prepared state *does* provide a complete description of the ontological object, but to observe and describe this state we need a non-classical, quantum-compatible notion of the macroscopic observations themselves in everyday thinking. While in its absence we can relate the observed states of **M** to classically conceived eigenstates, such eigenstates have nothing do with the ontological state. In other words, as long as we limit our observations to classically interpreted states of M, the wave function can have only instrumental significance. If we succeed in relating the observations to non-classical macroscopic states, however, then the wave function can have ontological significance. The constant ħ, as already hypothesized, quantifies the connection between these two views and allows either state of M to be invoked within the formalism. The two perspectives are thus complementary in the traditional quantum mechanical sense. I shall elaborate on these points further in the concluding section.

5. CLASSICAL AND QUANTUM-COMPATIBLE VIEWS OF THE MACROSCOPIC WORLD

Physicists may feel that it is impossible for the ontological superposed quantum state to co-exist with classically observed eigenstates, but this bias is just an artifact of our predilection to interpret the ontological states of M using the classical range of ordinary language (OL). That is, our natural tendency to distinguish macroscopic objects in terms of their positions in OL-based thinking leads us to impose the same ‘classical’ result on our mathematical model (which is essentially non-classical). As we have already shown, contradictions arise.

Could there be a range of *everyday thinking* in which the observable states of a macroscopic object can be distinguished non-classically? This possibility has not been considered so far. Quantum physicists, by and large, have followed Bohr’s fiat: ‘As a matter of course, all new experience makes its appearance within the frame of our customary points of view and forms of perception.’ [Bohr, 1927, 1]

The main purpose of this paper is to open physics to a new range of ordinary language notions suitable for reporting the laboratory events in quantum theory. I argue that there are *already* two complementary modes of ordinary language corresponding to *different* notions of haecceity, one classical and the other quantum-compatible.

Here a question naturally arises: if quantum theory applies to the macroscopic world in an irreducibly non-classical manner, how do we succeed pragmatically in applying the quantum formalism at the microscopic level while using the classical range of OL to interpret observations? I hypothesize that the two ways of reporting the observed states of a macroscopic measuring device using ordinary language are complementary and mutually exclusive within quantum physics, and that like complementary variables the two ranges of *ordinary language* may have a *quantitative connection* captured by ħ. Such a hypothesis makes it possible for the formalism to remain applicable within a classical view of the macroscopic world, although its practical value may be limited.

There is nothing in quantum theory that requires the superposed state (which evolves as per the Schrödinger equation) to 'go away' at a particular scale. Thus, quantum theory applies in principle to both the microscopic and macroscopic regimes. In contrast, under Born's rule the macroscopic realm is taken to be classical for all practical purposes. Once the statistical prediction of Born has been verified, physicists go 'backwards' and interpret the wave function and its evolution realistically. This quasi-classical approach to quantum realism has predictably produced immense conceptual difficulties. I propose that the Schrödinger equation can be *directly* related to observations (i.e., bypassing Born's rule) by adopting a quantum-compatible view of the macroscopic world in ordinary language that will use an as yet undeveloped quantum notion of haecceity. The two approaches will be mutually exclusive. (see Figure 1)

To illustrate this idea in experimental terms, consider the two-slit experiment. Our laboratory procedures can only prepare the state of the macroscopic source. Thus, the macroscopic source is the 'cause' of all observed events. Under the classical realist interpretation involving classical haecceity, however, the observation events are taken to reveal an absolute location where the detection event has occurred. This forces the conclusion that particles emitted by the source 'arrive' at the detector but without following a definite, linear trajectory. To explain this, one either adopts an instrumentalist viewpoint (that quantum theory only makes the right statistical predictions for these laboratory events to occur) or a realist viewpoint (collapse, many-worlds,

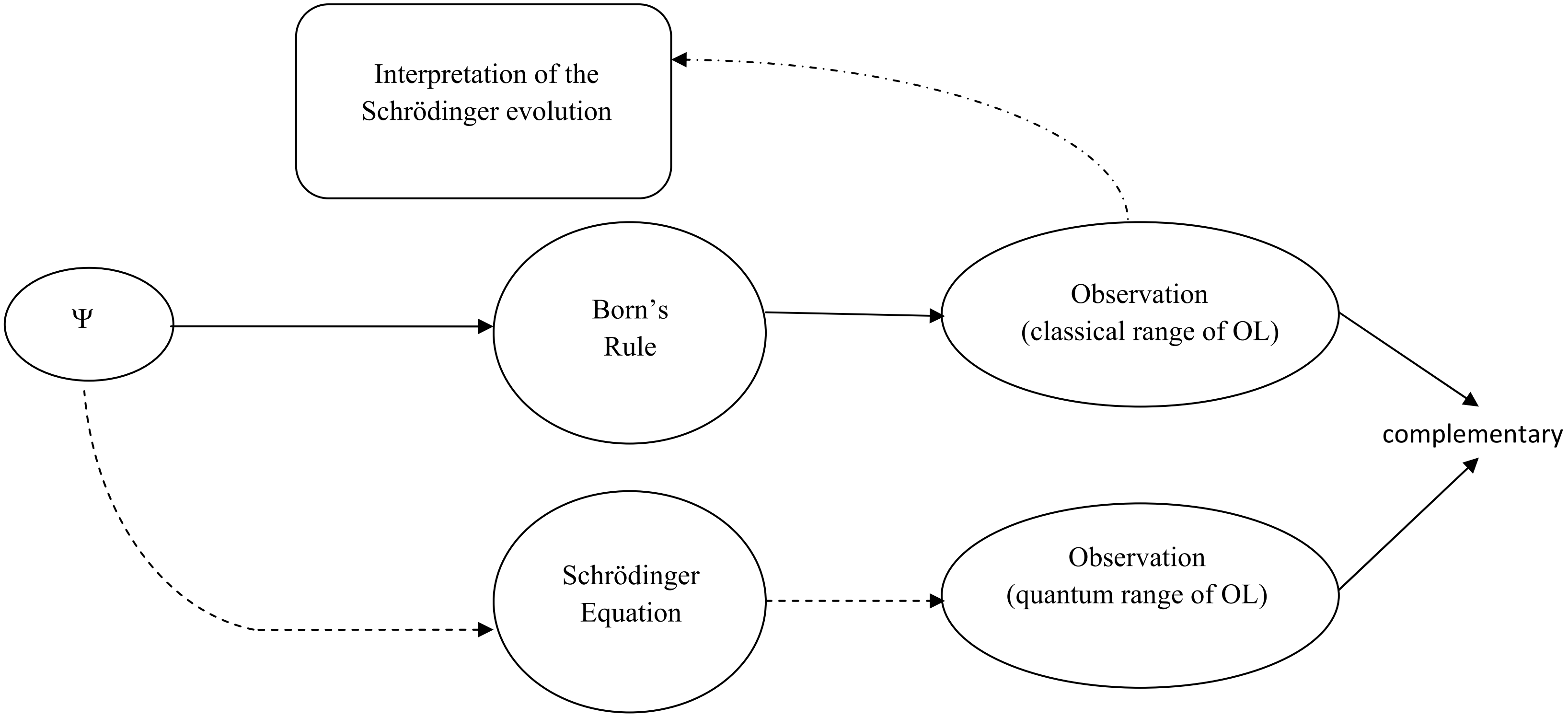

FIGURE 1: Presently, the psi function is first linked to the observations via the Born's rule (which presupposes classical haecceity). The evolution of the psi function as per the Schrödinger equation is *then* visualized accordingly.

It is envisaged that the evolution of the psi function as per the Schrödinger equation can be directly linked to the observations *sans* Born's rule, if we use a mode of ordinary language (OL) involving quantum haecceity. The two approaches will be complementary.

hidden-variable theories, decoherence). In either case, the ‘reality’ corresponding to a superposition state somehow gives way to a single classically definite result.

However, if we eschew classical haecceity with regard to macroscopic objects, the ‘detection’ will not pertain to a localized space-time event. The observable event (an audible click) can thus be linked to the macroscopic source itself, instead of to an ‘emitted’ particle. In this sense I hold that the microscopic and macroscopic applications of quantum mechanics are mutually exclusive, and depend on the mode of ordinary language – classical or quantum compatible – that we can freely choose to adopt.

5.1 THE ROLE OF ORDINARY LANGUAGE IN CONCEIVING MACROSCOPIC HAECCEITY

Whenever we interpret our experiences as yielding a definite space-time location, we are invoking the classical notion of haecceity. This is what I mean by treating observations ‘classically’. In this section, I will explore an alternative way of interpreting observations.

Recall that Schrödinger’s cat paradox presents us with certain facts that need to be reconciled if we are to avoid an explicit contradiction.

1. As per Born’s rule, quantum theory presupposes that macroscopic objects serving as measuring devices will always have classically determinate locations, regardless of whether they interact with a quantum particle in a state of superposition.
2. Indeed, when we observe M, we always have the *experience* of seeing M in a classically definite location.
3. Nonetheless, after interacting with a quantum particle in a state of superposition S, M must enter an observable state that uniquely corresponds to S.

Here, a vital but seldom noted distinction must be kept in mind: The *formal* state that any object enters in physics, and the corresponding states *observable* with our unaided senses are always and necessarily different. Even in classical mechanics, the variable x which stands for the property ‘position’ is never directly observable. It is a *formal* property of an entirely abstract entity: the ‘point particle’ in 3-dimensional Euclidean space. What we observe with our unaided eyes is the position of a macroscopic object in the lived world. Classical mechanics allows us to simply and uncritically connect the two.

We maintain this uncritical attitude even at the microscopic level in quantum theory. The theory tells us that a microscopic object is in a state of superposition formally. This is a state that we cannot observe directly with our unaided senses. On the other hand, a Stern-Gerlach device (for example) deflects incoming electrons in a state of superposition (say, with respect to its spin along the z- direction) to one of two distinct observable locations. We have reconciled this situation by adding the so-called projection postulate and a resultant "movable von Neumann cut" to the theory. This allows us to directly link a definite observation outcome with a formal state of the system (which is now an eigenstate), but at the price of deep conceptual problems.

But the projection postulate can be of no avail at the macroscopic level, where the observed quantum system and the observing system (the detector) are one and the same. Adding another detector (or any number of them, including a cat) will be of no use. For if we wish to say that the 'projection' of the superposed state of the first detector (into an eigenstate) occurs when it interacts with the second detector, then we have the situation where a dynamical interaction between two macroscopic objects is now quantum mechanical. This means that quantum mechanics needs to be applied to the macroscopic realm independent of present SQM, which is the main point of this paper anyway.

Under the circumstances, my proposal is that all three requirements of the cat paradox can be reconciled if we allow M to simultaneously exist in a classically determinate real state and *another* observable real state compatible with S, provided that both states can give rise to the *same observation experience*. That M can enter two such real states simultaneously that is the basic *premise* of the new approach I suggest.

However startling this proposal may seem, it is very much in line with our ordinary intuitions about macroscopic reality. Multiple interpretations at the level of experience, of the same underlying physical reality, are ubiquitous in everyday thinking. We can *simultaneously* interpret a printed page as displaying (a) simply a distribution of black color against a white background, (b) a medley of distinct physical shapes obeying an overall statistical distribution, and (c) an English text. In classical macroscopic realism, we would regard the 'objective reality' underlying all these experiences to be the same.

Similarly, we can *simultaneously* regard the same object in the external world as a stone, a paperweight, a doorstop, etc.

In these examples we interpret a single objective reality as different sense experiences. However, our proposed resolution of the cat paradox is based on the idea that different objective situations can also give rise to *a single sense experience*. A wealth of data in experimental psychology demonstrates that this situation is also ubiquitous in everyday thinking.

Consider, for example, the phenomenon of 'change blindness blindness (CBB)'. Simon and Levin (1997) report the following experiment. A researcher 'A' walks up to 'B', an unsuspecting student on the campus, and asks for directions. While B is responding, two persons carrying a wooden door rudely walk between them, momentarily concealing A from B's view. During this interruption, one of the people carrying the door changes places with A. In about 50% of cases, B thinks he is addressing the 'same' person even though the two are physically distinctive (height, weight, dress, etc.). This is an example of an observer interpreting two palpably different situations as the 'same'.

In another well-known experiment [See Clark, 2002; and references therein, McConkie, 1990; and O'Regan, 1990] a subject is seated in front of a computer screen which displays a block of intelligible text surrounded by junk characters. Unbeknownst to the subject, the block of text is shifting around the screen in sync with the subject's saccadic eye movements while the rest of screen is filled with constantly changing junk characters. The subject reports that the block of text is stationary, and that the screen is unchanging. Once again, objectively different physical situations give rise to the 'same' experience.

The general consensus is that all these experiments demonstrate a very loose fit between what is 'out there' and what we perceive even in our ordinary, daily experiences [See Noe, 2002 for an extensive treatment]. *Given* a realist commitment, they cast doubt on the 'classical' approach to understanding our cognitive experiences in relation to the outer world, wherein realism is taken to be synonymous with a one-to-one correspondence between our outer experiences and objective reality.

However, we always deal with our *reports* of our experiences, not just the experiences themselves. Even when contemplating experiences 'in our own head', we are obliged to use ordinary language. Thus, the role of ordinary language has to be fully taken into account to assess the possibility of a one-to-many relationship between reality and our experience. We can therefore ask, is it possible for us to use *ordinary language* to *report* our sense experiences in more than one way?

5.2 INTRODUCING THE IDEA OF MULTIPLE REAL WORLDS IN ORDINARY THINKING

In an earlier paper I have laid out a suitable terminology for classifying the relationship between ordinary language (OL) sense experiences and the external world (Gomatam 2004). Let ordinary language be designated to function in *P-mode* (phenomenal mode) when its propositions refer directly to our experiences. Let ordinary language (OL) be designated to function in *R-mode* (real mode) when it refers to a world outside of our experience.

Normally, the context of a discussion is supposed to identify in which mode the language is functioning. For example, 'the meter needle points to +1' describes an experience in the laboratory, and in this sense is primarily a *P*-mode statement. But the same sentence can be taken to describe what exists 'out there', in which case the language is said to function in *R*-mode.

Philosophical discussions have often treated everyday realism as establishing a direct link between the phenomenal world and the external world. I will presently argue that to properly understand everyday realism in *R*-mode we have to add the terminology of a 'real' world. Furthermore, naïve realism is equated with everyday realism. However, naïve realism is only one version of everyday realism. This is easily seen if we recognize that naïve realism consists of two parts. The 'realism' part assumes that any OL statement referring to the form of our experience (in *P*-mode) has a counterpart statement which describes the structure of the world that exists external to our experience (in *R*-mode). The 'naïve' part assumes that the *same* P-mode OL proposition will always serve as a description of the same objective situation underlying our sense experience. As I shall now show, it is possible to interpret a given *P*-mode statement in more than one way in *R*-mode. All such *R*-mode statements, being OL propositions, will qualify as everyday realism. If so, the distinction between the *P*-mode and *R*-mode of ordinary language makes it possible for everyday realism to remain intact even while naïve realism fails, as it does in statistical quantum mechanics. Consider, for example, one feature of the quantum mechanical description that is supposed to pose extreme difficulty for everyday thinking: the idea that a value registered by a macroscopic measuring device corresponding to a quantum mechanical observable (such as x, the so-called position observable) can be attributed to the system only at the point of an actual observation. However, there is more than one way of interpreting the concept ‘position’ in ordinary thinking. One alternative meaning of ‘position’ is, in fact, far more compatible with quantum theory’s requirement than that implied by classical haecceity.

Consider the statements ‘the pen is on the table’ and ‘the moon is inside the window’. Both describe the ‘position’ of an object as observed in personal experience. However, when interpreted in *R*-mode (i.e., as statements about the objective state of affairs), the underlying physical situations are very different in the two cases. In the case of the pen, it is possible for us to abstract out the table (on which it is lying) and think of its position as an absolute attribute in space. In the case of the moon ‘inside the window’, its position cannot be conceived as an absolute location by abstracting out the window. The reported position of the moon involves an *irreducible relation* between the moon (the observed object) and the window (the means of observation). The observing context (the window and the position of the observer) contributes as much to the perceived position as the observed entity (the moon). Consider this point well—while it is true that in physics all positions must be measured with respect to some other object and thus are relational, the second statement goes beyond this necessity. It describes a situation in which the observing conditions play an essential role in *defining* the property.

This is very similar to the situation in quantum theory. Even though we use the word ‘position’ to refer to the x-observable, and even though the formalism ‘works’ if we treat this observable as the absolute location of a single observed particle, it is equally true that the measuring device contributes as much as the particle to actualizing this observable.

The proposed *P*-mode and *R*-mode distinction allows us to objectify the difference between two uses of the word ‘position’. In fact, the distinction reveals two *different R*-modes underlying one and the same *P*-mode expression. In other words, the *P*-mode/*R*-mode distinction implies that there could be multiple ‘real’ worlds underlying our experiences, all describable using ordinary language (using different *R*-modes). This is in clear contrast to the usual philosophical discussion of everyday realism: the ‘external world’, being a metaphysical postulate, can never be directly described—especially using ordinary language. Indeed, Kant named each entity of the external world a ‘thing-in-itself’ and held that beyond this designation *any* OL reference can only pertain to objects of the phenomenal world. The *P*-mode/*R*-mode distinction, however, can help us advance beyond Kant’s stance. We can accept the metaphysical ‘thing-in-itself’ in the external world as indescribable, and let all OL statements refer to the phenomenal world of our experience—*but only in the P-mode*. What do *R*-mode statements then refer to? Since *R*-mode OL statements cannot refer to 'things-in-themselves', it is logically justified to introduce a 'real world' that is distinct from the external world. This real world can be taken to lie *in between* the phenomenal world (described using ordinary language in *P*-mode) and the external world (which is not describable using ordinary language). (See Figure 2.)

Upon this view, *R*-mode statements build and describe the 'real' worlds, which are now our conceptual models of the external world, described using ordinary language.

Can there be more than one such 'real' world, described using ordinary language? We already know that between the phenomenal and external worlds there can be multiple physics-worlds. For example, we can order certain experiences using either Newtonian mechanics (in the physics world of $R^3 \times R^1$) or the general theory of relativity (in the physics world of a 4-dimensional Riemannian manifold). (See Figure 3)

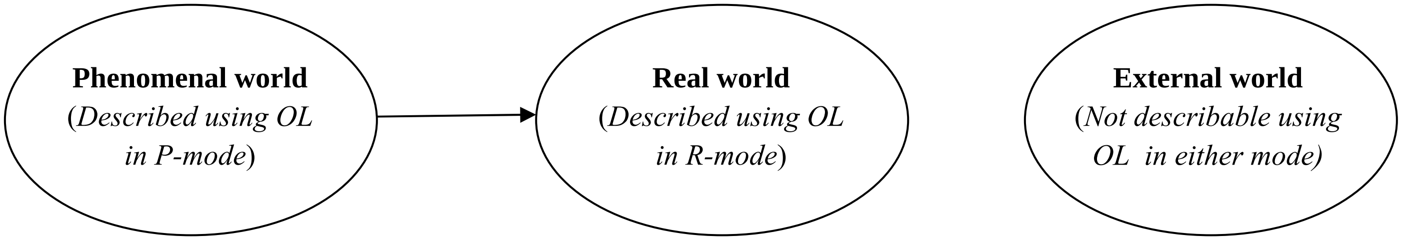

FIGURE 2: Since *R*-mode statements in OL can describe a world outside of our experiences, and since the external world cannot in principle be described using OL, there must be a 'real' world that is 'in-between' the phenomenal and the external world.

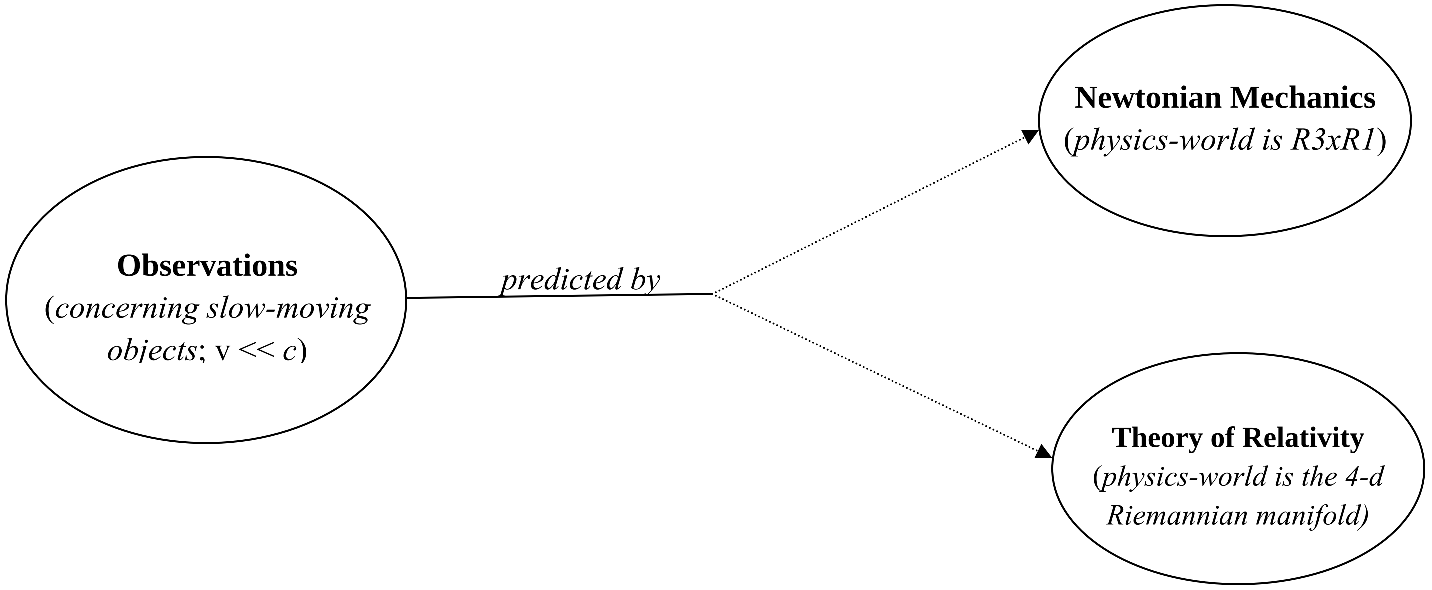

FIGURE 3: The motions of slow-moving objects (velocity < speed of light) can be accounted for by two different theories that feature two totally different physics-worlds.

More generally, physical theories are notoriously *under*determined. In principle there are an infinite number of physics worlds underlying the sum of observed phenomena; we choose among them using a range of physical intuitions (mathematical simplicity, 'elegance' etc.) and consider them justified only if they successfully predict new phenomena. Likewise, I propose that ordinary language be treated as a theory of the external world which can evolve, and that there can be multiple 'real' worlds (i.e., multiple *R*-mode descriptions of the external world, or Reality), and multiple phenomenal worlds (i.e., multiple *P*-mode descriptions). (See Figure 4)

If so, it makes sense that quantum theory should be capable of interpreting our *P*-mode observations in at least two different *R*-modes – classical (naïve realist) and non-classical (quantum compatible). This has been already shown in Figure 1.

To repeat, by recognizing the *P*-mode/*R*-mode distinction, we are rendering 'ordinary language' a 'theory' of the external world. Like our physics theories, we can allow ordinary language to evolve. Its *R*-mode can have multiple versions which we develop to keep pace with our physical theories.

Suppose that a theory in physics succeeds in predicting observations realistically using one range of R-mode language, but that its *mathematical formalism* is not amenable to realistic interpretation under the same R-mode. Quantum theory presents us with precisely this situation. Expanding our definition of realism from 'one-to-one' (naïve) to 'one-to-many' makes it possible to look for an alternative, non-classical range of R-mode language that can describe both P-mode observations and the mathematical formalism. Ideally, the new R-mode will also give rise to new testable predictions.

It is logically possible for multiple real worlds to exist where multiple R-mode expressions correspond to a single P-mode statement. (I made this suggestion in the previous section to resolve Schrödinger's paradox.) The next task is then to show that a given P-mode statement about our observation experience can be interpreted in more than one way in R-mode. A given P-mode report such as 'the meter needle points to +1' must be realistically interpreted via two *different* *R*-mode expressions, hence linked to two different objective states.

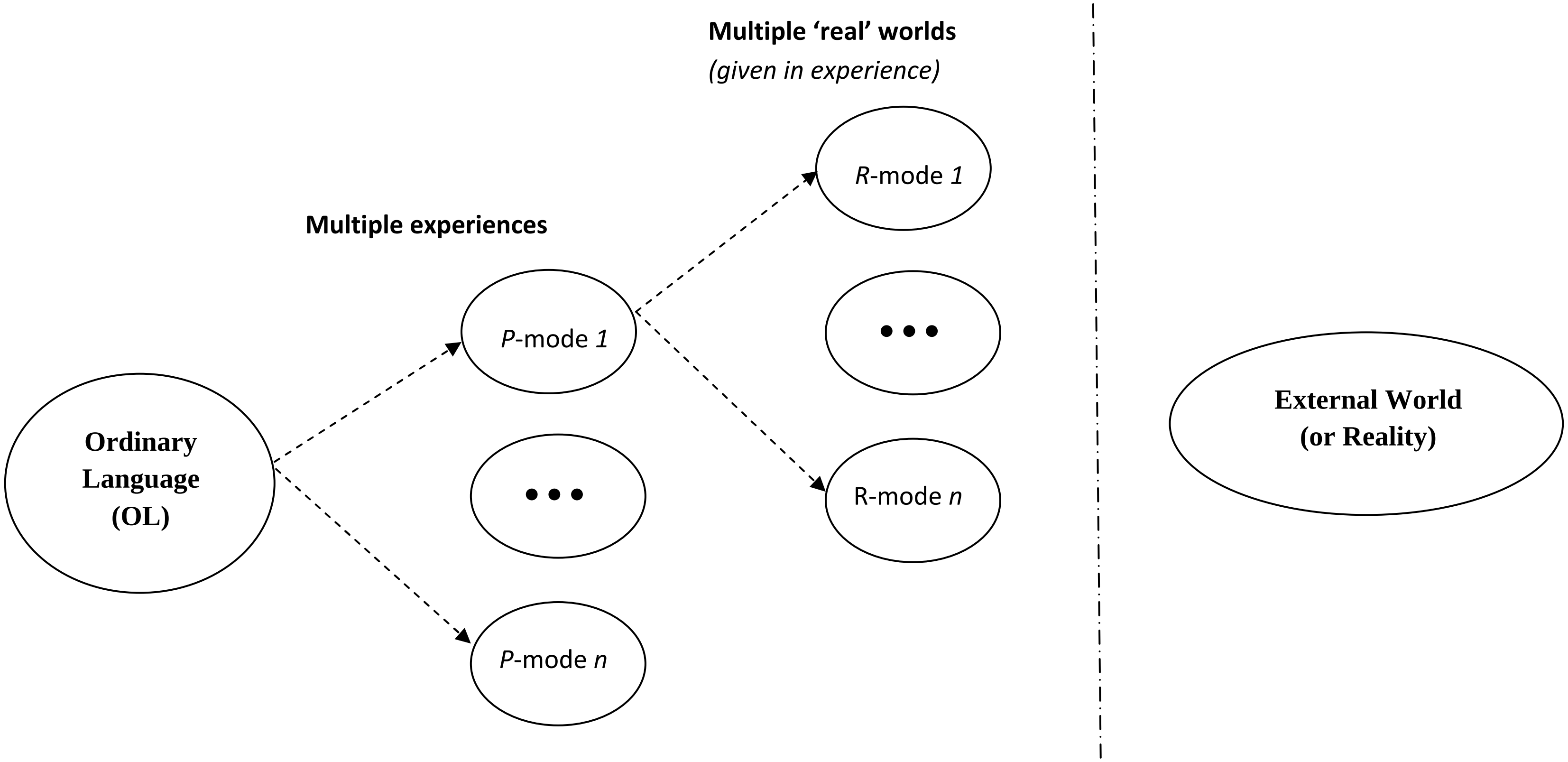

FIGURE 4: In the most general case, there can be multiple 'real' worlds (i.e. multiple R-mode descriptions using OL) of the one external world (or Reality). There can therefore also be multiple phenomenal worlds (i.e., multiple *P*-mode descriptions of our experiences using OL).

In such a situation, what fails in quantum theory is not everyday realism *per se*, but just the naïve part of everyday realism.

6. QUANTUM THEORY AND HUMAN EXPERIENCE

We can now examine my resolution to Schrödinger's paradox in greater detail. Let us consider once more the joint state |J> that arises when we apply quantum theory to a macroscopic measuring device M interacting with a quantum particle:

$$|J>= {}^{1}\!/_{\sqrt{2}}\ [|\Psi_1>|u> +|\Psi_2>|d>] \qquad [1]$$

Here |u> and |d> stand for the *formal* 'ket' states of M.

Thus, in interpreting the observable consequences of [1], we should know what the observable states of M that correspond to its formal quantum mechanical states |u> and |d> are, and expect to see them. However, we currently take the observable states of **M** to be classically determinate. Therefore, we ought not to be writing down the state of the joint system in terms of formal wave functions for M, since we have yet to apply quantum theory to the macroscopic world. Thus, in the absence of a macroscopic quantum theory *independent* of interaction between the two realms, the |J> state must refer to 'detector clicks' only as our observation experiences. Therefore, let us rewrite the |J> state as

$$|J'>= {}^{1}\!/_{\sqrt{2}}\ [\,(|\psi_1>(u)-\ |\psi_2>\ (d)\,] \qquad [2]$$

where (*u*) and (*d*) now simply stand for *our observation experiences.* This conception of the joint state correlates two possible observation experiences with two possible eigenstates. This statement only commits to one claim: if we make an observation upon the J' state, we will encounter each observation experience with a frequency of 0.5.

In this conception of the J' state, it does not make sense to ask 'what would our observation experience be prior to the observation?' Neither does it make sense to ask 'what is the real state of M prior to and independent of our observation?' The underlying 'real' states of **M** (which are non-classical and quantum-compatible) are unknown to us at present. We would *like* to replace the (*u*) and (*d*) terms by the formal quantum states of **M**, but our presumption is that this act requires an alternate conception of the real world underlying these observation experiences in *everyday thinking*. This is *not* an instrumentalist interpretation. All we are saying is that if we are going to interpret the observable consequences of a measurement upon the S state (the superposed state of a single particle) in terms of the classical *R*-mode (as we do in current statistical quantum mechanics), then the joint state of the single particle plus the **M** needs to be written out as *J′* instead of *J*, *provisionally*, until we find an alternative, non-classical R-mode of ordinary language that can relate the observable state of **M** more properly to the quantum formalism.

J′ is compatible with the so-called 'minimalist interpretation' of microscopic statistical quantum mechanics: quantum theory *does* give a description of the underlying microscopic physical reality (over and above its predictions of macroscopic laboratory events), albeit one that is entirely abstract, mathematical and non-visualizable. One can even go a step further by deploying the classical R-mode of ordinary language — referring to determinate states of M in the (classical) real world — to interpret the quantum mechanical formalism realistically at the microscopic level. This is precisely the approach attempted by various 'realist' interpretations in the literature, including the collapse interpretation, many-worlds, hidden-variables, decoherence, and many-minds. Such a quasi-classical realist approach has been fertile at the pragmatic level, helping physicists find new avenues of thought, design new experiments and find more practical uses for quantum states. The modern fields of quantum computation, quantum cryptography and quantum teleportation are but a few examples. However, the deeper problem of interpreting and understanding quantum ontology remains. This conflict has survived generations of theoretical advances (QFT, QCD, etc.), and in fact new problems have been added (such as renormalization).

I hope these arguments have clarified why I do not expect ontological interpretations of statistical quantum mechanics at the microscopic level to ever succeed in principle. All such interpretations are an attempt to 'fit' a quantum view of the microscopic world onto a classical view of observable macroscopic states. Logically, an ontological interpretation should first develop a non-classical view of the observable macroscopic world. This will be the subject of the next section.

6.1. OBJECTS AND KINDS — A NEW DUALITY

The main question of this paper remains to be asked and answered. Given a phenomenal experience (i.e., the observed state of M), how can we interpret the corresponding 'real-world' state in a non-classical manner? It is beyond the scope of this work to discuss this question in the context of physics—but I will attempt to do so in future publications. The remainder of this paper will be devoted to sketching out a rough map of the territory I expect to traverse in future research. In the main, I shall limit myself to pointing out that describing a non-classical conception of observable states is closely related to the task of finding an alternative to classical haecceity. Let us call this notion *quantum haecceity*, but use it to define the individuality of *macroscopic* objects.

How can one 'thing-in-itself' (an entity in the unobservable *external* world) give rise to two different real-world notions of what it means to be an 'object'? This question is much easier to answer than it may appear. I have already put forth one example of how we can visualize the 'real' world underlying our phenomenal world in two different ways even with regard to the elementary notion of 'position'. The example, 'the moon is inside the window' does not refer to the position of the moon as such, but 'our knowledge' of its position. Heisenberg, in a similar sense, spoke of 'a mathematics that represents no longer the behavior of the elementary particles [themselves] but rather our knowledge of this behavior'. [1958, 100]

Quite apart from the idea of position, ordinary thinking admits two different notions even of objects in the 'real' world. The first type is familiar enough and is invoked in classical physics: we will call it the OBJECT. Defined by classical haecceity, OBJECT is a universal class to which all things of the external world belong. Our experiences in the phenomenal world loudly hint that things of the external world can be also mapped on to a different real world (described in a different R-mode) composed of KINDS. A KIND is a subclass to which not all things in the world belong. For example, consider a macroscopic detector. It is certainly characterized by mass and other extensional properties in classical physics; in this description it is a generic OBJECT, no different from any other OBJECT in the classical world. However, we also regard this OBJECT as a *detector*. Most other things in the classical world would not qualify as a detector. The identity of the macroscopic entity qua DETECTOR is one instance of a KIND.

An OBJECT can belong to more than one KIND. Adapting a previous example, one and the same object can be classified under different KINDS: STONE, PAPERWEIGHT, DOORSTOP, WEAPON, etc.

We need to make the notion of KIND a bit more precise to link it to quantum theory. In this regard, two defining characteristics of KIND can be mentioned.

Whereas an OBJECT is ultimately defined in terms of its constituent matter, a KIND is not. A piece of wood and a piece of stone can both be paperweights. There are several examples of KINDS in physics that we can immediately connect to quantum theory. A blackbody has distinctive observable properties (its emission spectrum) that are independent of its composition. Any macroscopic thing acting as a blackbody can be described as either a classical OBJECT or a BLACKBODY (a KIND).

While quantum physicists would readily agree that a macroscopic blackbody meets this definition of a KIND, they have continued to treat measuring devices as OBJECTS (as I have already argued at length). Schrödinger's 'paradox' stands easily resolved: one and the same observation experience can be interpreted realistically in relation to either OBJECTS or KINDS, in two different underlying real worlds.

How does this tie in to our opening discussion of haecceity? It is evident from ordinary language that a given phenomenal object M corresponds to only one real OBJECT, since object is a universal class. However, the same phenomenal object can belong to many KINDS (as exemplified by the stone/paperweight/weapon example). This means that while a single phenomenal location always maps to a single location in the classical real world (housing OBJECTS), it can map to multiple KINDS in the quantum real world. Therefore, while location is sufficient to define haecceity in the phenomenal and classical worlds, it proves inadequate in the quantum real world. We need a new quantum notion of haecceity based on KINDS, not OBJECTS.

7. CONCLUSION

Schrödinger's 'cat paradox' argument has been shown to be a *non sequitur* within statistical quantum mechanics (SQM), since SQM presupposes (via Born's rule) the classicality of any measuring device **M**. Therefore, a cat interacting with M can never enter a state of superposition within SQM. Alternatively, within SQM there is no such thing as an observation corresponding to the quantum state of the individual **M** (the cat). However, this lack within SQM need not imply that there is no way to formally apply the quantum superposed state to an individual macroscopic object independent of SQM. We have proposed that this possibility exists if we can shift from the classical range of ordinary language (OL_C) to a quantum-compatible, 'non-classical' range (OL_Q). This is the central insight offered in this paper.

In this regard, I have further pointed out that the twin notions of **M** as OBJECT and KIND, already available in ordinary thinking, correspond well to classical and non-classical descriptions of the observable states of **M**. These two conceptions are complementary, i.e., mutually exclusive.

It is my expectation that while the classical conception of M using OL_C has enabled us to develop SQM, the non-classical conception of M using OL_Q will lead to a complementary macroscopic quantum mechanics (MQM). In OL_C, we interpret an observation experience as corresponding to a detection event occurring at some absolute location in the real world. In order to interpret a distant source S as the *cause* of observed events without 'action at a distance', we are thereby obliged to relate the events to emitted particles that 'arrive' at the detection site. Nevertheless, we are also forced to embrace nonlocality within SQM in EPR-like situations. If we can avoid ascribing a definite location to S and M, however, thereby avoiding classical haecceity, it is possible to link our observation experiences to the macroscopic source without mediation by emitted particles. In this manner we may be able to avoid quantum nonlocality at the macroscopic level. Clearly, the development of MQM using the notion of KINDS will require developing a new notion of quantum haecceity for macroscopic objects in everyday thinking and formalizing it.

It is of course a highly surprising suggestion that the wave equation could apply to two different observation contexts, and thus to micro and macro realms in a complementary manner. Under OL_C the eigenvalues of Schrödinger's equation pertain to specific locations where the emitted particles are found (or other derived observables). Under OL_Q, they would pertain to some as yet unknown properties of **M** qua KIND, and in turn to similar properties of the macroscopic source.

We are now ready to discuss the relation between such an MQM and SQM. MQM, if developed, will be complementary to SQM in the sense that SQM is applicable ONLY to the micro regime (it presupposes the classicality of the macro realm), while MQM (at least as of now) is only applicable to the macro realm. Naturally, MQM will also be complementary to classical physics.

Will MQM be a more complete description of the macroscopic world? Classical physics can be considered a “complete” description of the macro world treated in terms of generic objects. MQM will also be a complete description of the macroscopic world treated in terms of kinds (since Schrödinger’s equation is also deterministic, and MQM will invoke it *sans* Born's rule). But I expect classical physics will come to be seen as an ‘effective’ theory also in comparison to MQM, which will be a more fundamental theory. All this will take the notion of complementarity in quantum mechanics to a level deeper than what Bohr offered.

What then will be relation between MQM and general theory of relativity? This question must be left open at this stage of development of MQM.

What I have offered in this paper is not a specific solution to the measurement problem within SQM, but a *research programme* to solve the open problem of applying quantum theory to the macroscopic realm (MQM) without the description reducing to classical physics at the point of observation. However, the road from here to MQM is long and will doubtless require jettisoning other ideas currently enshrined within SQM. These will be the subject of future papers.

ACKNOWLEDGEMENTS

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NOTES

1. Direct analogy from simple quantum mechanical systems would seem to argue against this possibility, but consider the nucleus. This system is formally represented by a superposed wave function, which determines its energy levels. In practice, however, the full wave function is usually too complicated to write out. Physicists have found alternative means of working with complicated yet undeniably quantum systems.

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