

Quantum Objects

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Abstract:

In this paper, we suggest an alternative interpretation for the quantum state vector, which, by considering *temporal parts* for physical objects, aims to give an intelligible account of measurement problem in quantum mechanics. We examine the capacity of this interpretation as for explaining three measurement problems: the problem of outcome, the problem of statistics and the problem of effect. We argue that, this interpretation of the state vector, while providing a satisfactory account, as *rationaly plausible as* its rivals, for the measurement problem, shows yet another limitation of our perceptual experience, i.e. our inability to perceive *unsharp reality*.

Keywords: Measurement problem, interpretation of quantum mechanics, four-dimensionalism, unsharp reality.

1. Introduction

The so called measurement problem, from the inception of Quantum Mechanics (QM), has been one of the most controversial problems, and there is no general agreement, among both physicists and philosophers of physics, even on the problem *itself*. Despite the fact that some authors, like Bub (1974:140), have taken the measurement problem as a “pseudo-problem” arising from “a misunderstanding of von Neumann’s problem”, others have suggested various models and interpretations, each of which is based on a specific construal of the problem with a different focus, to solve it. According to Albert’s formulation of the problem, for instance, “The dynamics and the postulate of collapse are flatly in contradiction with one another (just as we had feared they might be); and the postulate of collapse seems to be right about what happens when we make measurements, and the dynamics seems to be bizarrely wrong about what happens when we make measurements; and yet the dynamics seems to be right about what happens whenever we aren’t making measurements.” (1992:79). To be more precise, as Maudlin (1995) explained in his paper, entitled “Three Measurement Problems”, the following three claims about QM are mutually inconsistent:

A) The wave-function of a system is *complete*.

B) The wave-function always evolves in accord with a linear dynamical equation.

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C) Measurements of, e.g., the spin of an electron always (or at least usually) have determinate outcomes, i.e., at the end of the measurement the measuring device is either in a state which indicates spin up (and not down) or spin down (and not up).

To see the inconsistency of these three claims, consider, For example, a good z-spin measuring device, which has a ready state ($|ready\rangle$) and two indicator states (call them "UP" and "DOWN". The device is so constructed that if it is in its *ready state* and a z-spin *up* electron $|+z\rangle$ is fed in, it will evolve, with certainty, into the "UP" state $|"UP"\rangle$, and if a z-spin down electron $| -z\rangle$ is fed in, it will evolve, with certainty, into the "DOWN" state $|"DOWN"\rangle$. Using obvious notation:

$$|+z\rangle|ready\rangle \rightarrow |+z\rangle|"UP"\rangle, \text{ and}$$

$$|-z\rangle|ready\rangle \rightarrow |-z\rangle|"DOWN"\rangle$$

If we feed in this device an electron in an eigenstate of x-spin rather than z-spin, since

$$|+x\rangle \rightarrow 1/\sqrt{2}|+z\rangle + 1/\sqrt{2}|-z\rangle$$

then according to the claim B and linearity of the evolution, the initial state must evolve into

$$(1/\sqrt{2}|+z\rangle + 1/\sqrt{2}|-z\rangle)|ready\rangle.$$

But the question is what kind of state of the measuring device this represents:

$$|S\rangle = 1/\sqrt{2}(|+z\rangle|"UP"\rangle + |-z\rangle|"DOWN"\rangle)$$

If A is correct, and the wave-function is *complete*, then this wave-function must specify, directly or indirectly, every physical fact about the measuring device. But, simply by symmetry, it seems that this wavefunction cannot possibly describe a measuring device in the "UP" but not "DOWN" state or in the "DOWN" but not "UP" state. Since "UP" and "DOWN" enter symmetrically into the final state, by what argument could one attempt to show that this device is, in fact, in exactly one of the two indicator states?

So if A and B are correct, C must be wrong. If A and B are correct, z-spin measurements carried out on electrons in x-spin eigenstates will simply fail to have *determinate* outcomes. This seems to fly in the face of Born's rule, which says that such measurements should have a 50% chance of coming out "UP" and a 50% chance of coming out "DOWN, simply because occurrence of outcomes is taken for granted within such a statistical framework.

To resolve the contradiction, people have pursued different strategies. In some theories, like GRW, dynamics has been modified to a nonlinear one, and in some others, like Bohm's model, it has been postulated more to physical reality than is represented in the wavefunction - namely, *hidden variables*. In yet another strategy, Everett-like theories, abandoning the very collapse postulate, have extended their ontology to many worlds, many minds, etc. In this paper, following the last strategy, by considering *temporal parts* for physical objects, taken as some sort of extension in ontology, we suggest an alternative interpretation for the quantum

state vector. This interpretation, according to Maudlin's analysis, must overcome the "Three Measurement Problems":

The problem of outcomes. In QM, we encounter with some weird superposition states, which are linear combination of some pure states. The problem associated with these superposition states, which are themselves pure and independent, is that, after measurement process, the system randomly chooses one of the states in the superposition and eventually ends up with a *determinate* possible value for the associated observable quantity. In fact, "It is just the usual understanding of the *Schrodinger cat problem* laid out in a formally exact way. Oddly enough, when so laid out, it becomes immediately evident that a fair amount of the work in the foundations of quantum theory misses the mark. The most widespread misunderstanding arises from the claim that the measurement problem has to do with *superpositions* versus *mixed states*." (Maudlin 1995:9)

The problem of statistics. QM suggests probabilistic results satisfying Born's rule. Measurement situations, started with the same initial wave functions, could lead to different outcomes. The Probability of obtaining each outcome is in accord with Born's rule. The problem is present when wave functions evolve according to the linear dynamics. Why similar wave functions end up to different outcomes, in accords with Born's rule?

The problem of effects. This problem emerges from the fact that, according to standard interpretation, in measurement processes, collapse changes the state of the system, and so influences its future development. The state of the quantum mechanical system after measurement should be an eigenstate corresponding to the measurement outcome. The main motive for considering such a condition is that measurement is *repeatable*. To attain repeatability, the system after measurement should be in an eigenstate corresponding to the relevant observable, so that the second measurement, which is done *immediately*¹ after the first, yields with probability 1 the previous result.

Every proposal for tackling the measurement problem should have enough resources to give a satisfactory account of these three problems. Facing these difficulties, many physicists and philosophers have called for some new satisfactory conceptual schemes and categories. Moving in this direction, we are about to suggest a new interpretation for the quantum vector state, while giving a satisfactory account for the measurement problem, we believe, is as *rationally plausible* as its rivals. To begin with, we first illustrate a new picture of observation and measurement, which our interpretation is based on.

2. Observation and Measurement in the New Picture

According to a view about physical objects, which is called three-dimensionalism (3D), objects persist through time by "enduring,"² that is, by being wholly present at all times at

¹ As for 'immediately' condition, it is only important that, at the time of the second measurement, Schrödinger evolution does not change state of the system.

² 'enduring', 'perduring', and 'stage' are borrowed from *temporal parts* and *four-dimensionalism* debate terminology and literature. See for example Hawley (2010) in SEP.

which they exist. In this account, the system cannot be in two states A and B at the same time; observing it always ends up having a determinate value for the relevant quantity. Based on such a picture and presupposition, if there is a theory for description of the physical reality, attributing superposition of states A and B to a system, then we would be in trouble to *interpret* how the system could be in such a weird state. So we might consider this description of physical reality incomplete, (i.e., there should be some other parameters and variables to specify whether system is in state A or B, or the theory is simply false.

There is, however, yet another way out of this dilemma, by suggesting an alternative picture for evolution and observation of system, while, it is claimed, is consistent with superposition states. To do this, we emphasize that, QM needs to introduce new conceptual scheme to overcome its difficulties. By appealing to some advantages of the new interpretation of the vector state, we will show that solving the measurement problem in QM requires a four-dimensional ontology of *objects*, according to which, objects persist four-dimensionally through time with temporal parts that is, by being temporally, as well as spatially, extended.¹

Based on this interpretation, the physical object coincides with time and, like time, it is a *continuum*², which has *flowing*³ *temporal parts*: the outcome of measuring an observable of the system, *at this moment*, is always something *other than* the outcome we would obtain in another measurement event at some other time, past or future. At each time slice, what is observed is a *new stage* (or a temporal part) of a flowing unsharp observable (or a four-dimensional object) at every moment of time. In other words, as time passes, the old stage of the preceding observable is annihilated and the new stage of it comes to exist in its place, and this renewal happens *continuously* at every moment. ‘Countinous’, here, implies that the mixture is an *improper*, as opposed to be a *proper* mixture, of instant sharp observables in an interval of time. The *unsharp observable* is continuous and unified like a continuous spectrum, and so, actually, it is a *unified continuous reality*. So objects are thought to have instantaneous temporal parts (‘time-slices’), which do not themselves persist through time. This mode of reality, in its totality, cannot be *wholly* exist simultaneously and cannot be *wholly* found at every moment of time, but its *totality* exists in its whole lifetime. For an intuitive picture, consider the following scenario.

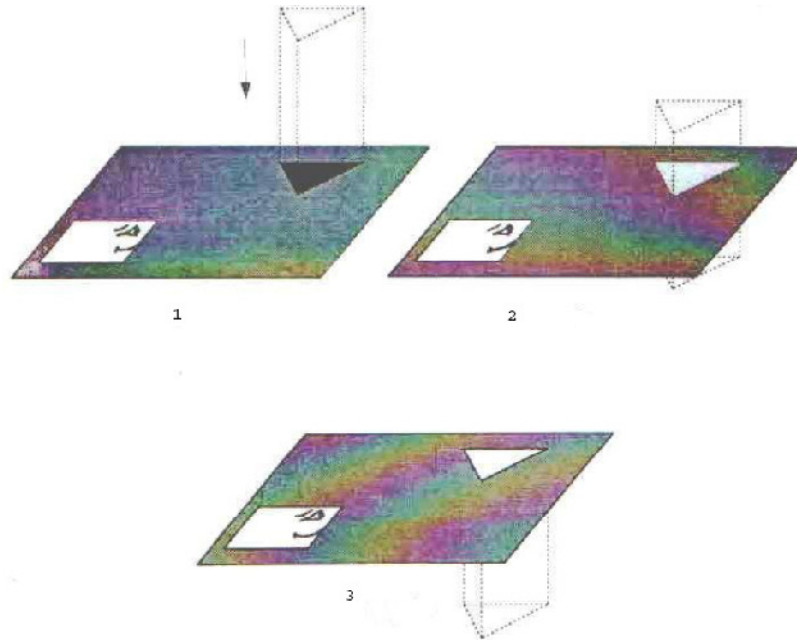
Imagine an observer who is an inhabitant of a flatland, a two-dimensional world populated by beings having only two spatial dimensions and wholly confined to a surface. For simplicity, let this surface be a plane. Now, suppose that he/she is presented with an

¹ The original idea of this paper was under the influence of the ontology of Sadra's philosophy (1571–1641), especially, Obudyyat's (2006/1385). This idea was completed by recent attempts in four-dimensionalism ontology and its applications in physics. In this regard, especially, Balashov (1999) was provocative.

² The main feature of a *continuum* is that it is hypothetically divisible. That is, for every *moment* of time, there is always an instant, *after* that *moment*, which can be, in relation to that moment, considered as *future*, and an instant, *before* it, which can be, in relation to that moment, considered as *past*.

³ A continuum could be *persistent* or *flowing*. *Persistent* continuum, like line, area and volume, is a continuum whose parts exist altogether. However, none of the two hypothetical parts of a *flowing* continuum, like time, exist together.

object, for example a pyramid. As it is shown in the following picture, the flatlander perceives reality only in two-dimensional plane, and has not any perception of the third dimension; in other words, his situation made him incapable of perceiving the third dimension. He is ignorant of what there *is*, in the other dimension, external to his plane.



Now imagine a *purely* and uniformly colored in black pyramid with a triangle base; this pyramid is in a *pure state*. Before the pyramid enters to the plane, there is nothing for the flatlander. But when it enters into the observer's world, and when the plane intersects with the pyramid, the observer sees *only* a cross section of the pyramid, i.e. a black triangle. This triangle persists to exist for the flatlander by enduring through time interval in which, the pyramid passes the plane. As a matter of fact, flatlanders perceive two-dimensional slices.

Now imagine another observer who perceives the third dimension. He would realize how the observer in the plane could see the pyramid: the flatlander *falsely* thinks and reports, at a moment of time that a triangle comes to exist, and after passing some time, it is annihilated. But the situation for the second observer is radically different as no triangle being observed. Therefore, from the second observer's point of view, what the flatlander perceives, is in fact a 'hypothetical' cross section of the pyramid with the plane. Moreover, the flatlander, because of the pure black color of the pyramid, has the *illusion* that there is only one and the same triangle, which would come to exist, persists in the time interval, and it has never undergone a change or evolution. This is an *illusion*, however, from the second observer's point of view, which is outside the plane. He knows that the flatlander has never seen the same triangle in any two moments, but because these triangles are in complete similarity with each other, it *appears* to him as only *one* persistent triangle. He has observed different triangles, which are temporal parts of a 3D object, i.e. the pyramid, at different instants of time.

The two observers both give a true description *for their observations* but, by considering the additional dimension, the description of the second observer is more complete. One might

ask whether the flatlander could reach to the second observer's picture at all. Certainly, he could, but not by direct observation. He could reach that picture by imagination, theorizing or mathematical abstraction.

Therefore, according to our accounts, picture of objects, if we accept that objects and physical systems have temporal parts, it follows that the sentient observer always perceives only a part or a stage of the unsharp observable of a flowing system, since mental experience occurs momentarily. As it was said before, the flatlander never sees the three-dimensional pyramid, and only sees a cross-section of it. In the same vein, observers in a measurement process never see the whole of the flowing system, which coincides with time. Rather, in every measurement and observation, the observer sees only the hypothetical cross-section or a stage of it, which is in its plane. In our example, though it *appears* to the observer that he sees the same triangle, but, in fact he sees a new triangle at every moment of time. Similarly, our observer in the measurement process has the same feeling as regards the observing system. That is, it *appears* to him that he always sees *the same* system, while the system is always becoming new. He is not able to feel the evolution of the new system, by the same reason that applies to the flatlander. Those triangles that the flatlander sees, are not discrete from each other, rather they are all 'hypothetical' cross-sections of a continuous persistent system. The determinate values observed by the observer are *not* 'discrete' and 'isolated' from each other. It is also not the case that the observer measures the observable independent of what he has observed or what he will observe. All of them are hypothetical continuous cross sections (or temporal parts or temporal stages) of what is called a *flowing* system.

In the flowing picture, therefore, the system, with all of its unsharp properties, evolves altogether, but the observer *thinks* that the system (or other properties of the system), is at rest and does not evolve. It appears to him that, in every moment, the system exists with all of its sharp properties and sharp observables. After that moment they are all annihilated and the system with all of its observables are simultaneously renewed again, and so on. This happens, however, in a way that these *becoming* sharp realities, in sum, create a *flowing* object, without any *discontinuity* between *becoming sharp realities*. Based on this picture of reality, we give an interpretation for the quantum vector state.

3. Interpretation of the Quantum Vector State

Unless we change our interpretation, it would be meaningless to say an electron, which is in a superposition state, is in several positions. Many interpretations have been suggested for such weird states, and for explaining how it could be reconciled with our definite experiences. In the many worlds interpretation, for example, there are several copies of electron in different positions in different worlds. This is, however, not the only way out. The *Sigma interpretation*¹, based on the picture of observation and evolution presented in previous section, is another way of attempting to do, like the many worlds, without the collapse.

¹ 'Sigma', or Σ , denotes *summation* or *superposition*, which the Sigma interpretation (SI) takes it as *real* and *genuine*. It is also the first letter of Sadra the philosopher (1571–1641).

Sigma makes two physical claims: I) The state vector of a system completely describes the physical reality of that system. II) The state vector evolves in accordance with Schrodinger's equation. The problem, as we have seen, is how to square II with the appearances and especially with the definiteness of our experience. According to this interpretation, if we understand the state of the system in a certain way, we will see that the collapse and the probability interpretation emerge as features of the theory. The state of the system $|S\rangle$ can be represented as a superposition thus:

$$|S\rangle = c_1|a_1\rangle + c_2|a_2\rangle \dots$$

where the a_i constitute a complete set of basis vectors that span the Hilbert space for the whole system. Our suggestion is that each of the components of the superposition be thought of as representing the density of the local state, in which, the temporal parts of the flowing system are created or renewed.

How can the flowing object save the appearances? Suppose that an observer M measures the x-spin of an electron e in an eigenstate of z spin. Let +z be the state z-spin "up", +x (-x) be the state x-spin "up" ("down"), B_0 be the state of the observer prior to making the measurement and +B (-B) be the state of M observing that x spin is up (down). Before the measurement the state of the System is $|B_0\rangle|+z\rangle$. At the conclusion of the measurement the state of the system (observer+electron) is

$$1/\sqrt{2}(|+B\rangle|+x\rangle + |-B\rangle|-x\rangle)$$

According to the Sigma, the flowing electron has been renewing, has been creating, *at every moment*, in "spin-up" OR "Spin-down". So, when M measures the spin of the electron, she observes definitely "spin-up" OR "spin-down". Each time she has a perfectly definite experience corresponding to the perfectly definite stage (temporal part) of the electron.

So, we take wave function as a description of a flowing system. In the flowing picture, *at every moment*, only a *cross-section* or a stage of the physical system, not *the whole* physical system, could be found. Moreover, the observer finds every cross-section or stage only at *a moment* and it is not possible for *an individual stage* to be found at every moment¹.

According to this interpretation, the state vector could be considered as a description of a single isolated system. Whereas the wave function describes the system as a *flowing* object, probability finds a new meaning; obtaining a determinate outcome in a measurement process is related to the statistical distribution of *potential* stages and states of the flowing system, which are reflected in the superposition state. The system, therefore, is always in motion and evolution during its entire lifetime, and their *becomings* happen with a new value for the observable, but in its entire lifetime. The probability attributed to the renewals, however, is

¹ As in Everett's (1973:61) interpretation, this result is independent of the *size* of the object, and remains true for objects of quite macroscopic dimensions. That is, they are also *flowing* reality, which are followed by the fluidity of their parts. So, Sigma interpretation, as Everett's (1973:87-8), gives a unified description of micro- and marco-objects.

governed by a specific distribution, i.e. according Born's rule¹, and, of course, at every moment of time, the distribution of temporal parts of the “quantum object”, described by the quantum state, evolves according to the time-dependent Schrödinger equation.

von Neumann's interpretation of state is *not* realistic, and takes it merely as a *theoretical construct*. On the contrary, in the Sigma interpretation (SI) as in Everett's, state vector refers to a real state of affairs. From a realist stance regarding quantum states follows the reality of superposition states and their implicit indeterminacy. Indeed, according to the SI, the system is *principally* in a superposition state but, when according to the standard view, the system is in pure eigen-state, the terms in the superposition are the same; even when system is in a *pure state*, it should be interpreted that the system is in continuous renewals in ‘states’, which happen to be, in complete similarity. So if the state of the system is in the superposition of states corresponding to the black and white color we should not interpret it as “being black and white” probability, rather we should talk about probability of “becoming” black or white. That is, the system at every moment is *becoming* black and white. Of course, the system, in its renewal and becoming, has sharp observable quantities, but these quantities do not have *distinguishable* values. All systems and states, therefore, even when they *appear* to be at rest, are in continuous renewal and becoming.² One may object that there is nothing to identify these renewal states as constituting the same individual's experience. In replying to this objection, it should be noted here, in passing, since, in the SI, the *reality* of superpositions preserves trans-temporal identity of systems, this perpetual renewal does not violates the *identity* of the physical system.

4. Problem of Outcome

If wave-function is considered *complete*, then it must specify every physical fact about the composite system and the measuring device. But by what argument could one attempt to show that the composite system, in a superposition state, gives actually in exactly one determinate outcome? That is the *problem of outcome* in the measurement problem.

According to the mentioned account, and using Balashov's (1999) terminology, the relation between the spatial properties of the pyramid and of the triangles perceived by flatlanders is a rather *intimate, ancestral relation*. The 2D shapes are directly “inherited” from the 3D shapes, as being constituted by one-dimensional sides fully belonging to two-dimensional edges of the original three-dimensional object. It is an *objective* feature of the way in which Flatland as a whole is situated in the wider three-dimensional “superspace.” The main discovery of the Flatland physicists is the discovery of this objective, ontological feature to which they have been led to by an argument to the best explanation. A hypothesis

¹ So, based on this interpretation, it is *not* compelling to take probability or chance as an *inherent* feature of the world. As in Ballentine's statistical approach, perusing hidden variables is legitimate. Above all, it is still necessary to provide an explanation for the specific distribution governs renewals.

² This is very similar to Bohm's ‘*holomovement*’ concept. The idea that everything is in a state of flow or becoming (or what he calls the “universal flux”). For Bohm, wholeness is not a static oneness, but a dynamic wholeness-in-motion, in which everything moves together in an interconnected process. See (Bohm & Hiley 1993:355), (Pylkkanen 2007:25), and Bohm (1980:11)

could be put forward, by the physicist of the Flatland, that the triangle is a cross-section of a three-dimensional being and it ought to be a pyramid situated with respect to Flatland as shown in the above Figure.¹

In the relative-state interpretation, all possible measurement outcomes are considered equally real for a fictitious, non-existent(or global) “observer” outside the Universe who views the universal state vector, whereas for each observers inside the Universe it is always one particular value of the measured observable that is real. In the same vein, in the SI of the measurement process, the relation between unsharp observables and determinate outcomes, perceived by the observer, is a rather intimate, ancestral relation. The determinate outcomes, which the observer perceives, are slices of a flowing unsharp reality, which from an *atemporal* observer's standpoint, *indistinguishably* sit beside each other. The usual observer, because of his limited perceptual ability (that is because he cannot have a perceptual experience of the whole system at a moment), can only see a determinate outcome. In other words, as any observer's experience happens at a moment of the continuum of time, and as the observer observes the system from a lower dimension and intersects with the flowing reality, only at a moment or at a point of flowing continuum, he inevitably sees a determinate outcome. After all, we cannot observe total lifetime of an entity or even a part of it at a moment.² Accordingly, as in many-worlds interpretation, in which determinate outcomes in every world explain *empirical content* of the theory, in the same manner, in the SI, temporal parts of the fluid object, which are *indistinguishably* determined at every moment, account for the *empirical content*.

In hidden variable theories take it for granted that *experience* gives us a ‘complete’ description of reality; since we experience *determinate* outcomes, we conclude that reality is completely *determined*. On the other hand, since, in quantum mechanics, we encounter superposition states, which imply an *indeterminism*, so we eventually have to hold quantum mechanics as incomplete theory. After all, it could not have yielded a representation for *determined reality* (the reality we reached, based on our sense experience). Accordingly, there needs to be additional parameters to make it complete. According to the SI, however, contra what a hidden variable theorist believes, our experience *does not* give us a ‘complete’ description of reality and the determinate experience comes from our inability to experience indeterminate superposition or *unsharp reality*. In fact, we encounter a situation which can be described by *Duhem-Quine thesis*. The SI *prefers* to take the *appearance* of ‘determinate outcomes’ as a *product of our mind*.³ Although we are unable to have a perceptual experience

¹ Here, we have almost used Balashov's exposition of the scenario (1999).

² Contra Everett's theory in which all elements of superposition states represent *actual* realities which simultaneously exist, in Sigma interpretation, elements of superposition state represent *potential* realities which *briefly and indistinguishably* exist in a *flowing continuum* represented by the superposition state in its totality. This is followed by the fact that in Everett's theory, superposition state represents a persistent system, which exists through time by enduring, while Sigma theory interprets superposition state as a *flowing continuum*.

³ According to von Neumann, as far as formalism of QM concerns, there is no *physical* collapse, and we encounter with superposition states. To obtain determinate outcomes, he believes in a *mental* collapse. On the other hand, for any determination in mental level, it seems that there should be a correspondent determination in *physical* level. Handling this problem, von Neumann suggests an *arbitrary* distinction between observed system and observer (von Neumann 1955:421), Becker (2004). Although this “arbitrariness” does not explain *why* and

of superposition state¹, we could reach to those indeterminate superpositions by theorizing or mathematical abstraction, as we reach the heliocentric picture of solar system by theorizing, rather *direct* observation or sense experience.

By these considerations, we hold a realist position about superposition states by taking superposition states describing a mode of existence of a reality and its temporal parts. These temporal parts have a *brief* and *potential* reality in superpositions, *not* in the sense that those states *do not* exist outside of the superposition, and they are *not* real.² They are *real* but not in an *independent* and *distinguishable* way. So in the SI, superposition states of dead and alive cat represents *unsharp reality* of dead cat state and alive cat state. The superposition state of cat describes Schrodinger's cat from an atemporal point of view and describes it as a flowing system with an *unsharp reality*. So, the state of cat is *potentially* both dead and alive. Not in the sense that cat is *not* alive (dead) now, and at this moment, and can be alive (dead). But in the sense that the cat's flowing reality, can be found alive (dead) by *cutting* the flowing reality of cat, i.e. by *measuring* it and by *participation of mind and consciousness* in the process.^{3,4} It should be noted that, in the Sigma model, obtaining a determinate outcome is the result of the *special metaphysical relation* of the observer as regards to the system, *not* the special role of the measurement. That makes the state of the observer to depend upon the system. It depends on which plane it cuts the flowing system. This *relativity* is not also a newborn feature. Copenhagen and Everett's interpretation have this feature too.⁵ In the Sigma model, however, there is an explanation for it. The dependency of sub-systems to other parts of the composite

how the collapse occurs, the SI claims to explain it by suggesting a new *ontology and conceptual scheme*. It should be noted that the '*product of our mind*' does *not* mean that the determinate outcomes are *not real*. They are *briefly and indistinguishably* exist in a *flowing continuum* (see footnote 2, p. 9).

¹ The relation between mental states and physical states is not supervenience. The same is true for Bohm's, von Neumann's and Everett's model, either.

² Heisenberg (1958:53), used the idea of Aristotelian 'potentia' in his later work on the foundations of the quantum theory. He goes beyond the usual interpretation of the pure quantum state as the catalogue of all actual properties—those with probability equal to one—of an individual system in that he considers ψ as the catalogue of the potentialities of all possible (sharp) properties Q of the system, quantified by the probabilities $p_\psi(Q) = \langle \psi | Q \psi \rangle$. The notion of *actualization of potentialities*, then, makes it possible for one to "say that the transition from the 'possible' to the 'actual' takes place as soon as the interaction between the object and the measuring device, and thereby with the rest of the world, has come into play; it is not connected with the act of registration of the result in the mind of the observer." (1958: 54-55). Potentiality has been also articulated by Shimony (1993:179) as a *modality of existence* of physical systems. But Heisenberg and Shimony's conception of "potentiality" is not in *temporal parts* context.

³ So, Copenhagen interpretation is right, *in a sense*, when it says that we have a *determinate* outcome *just after measurement*, but the importance lies in *explaining* it. the meaning of this claim is *criticizable* and rational only in a metaphysical framework, not by denying metaphysics and ontological theorizing.

⁴ In another project the concept of *unsharp quantum reality*, though *ontologically* different from ours, has been also suggested, and a particular way of formalizing it was explored by Busch *et. al.*, (1996) to explain quantum indeterminacy and measurement problem. However since, in this approach, there is no room for the role of *mind*, it requires a stochastic modification of the unitary time evolution postulate for quantum dynamics. See Busch & Jaeger (2011).

⁵ Bohr criticized EPR's 'physical reality criterion'. According to Bohr, this criterion is essentially ambiguous because it is proposed without considering experimental *arrangement* (Bohr 1935:697). According to the *fundamental relativity of quantum mechanical states*, in Everett's *relative* state interpretation, likewise, we speak of observer's state *relative* to the system's state.

system, moreover, explains both indeterminism and continuum-ness, and it means that the whole has an *ontological priority* to its parts.¹

4.1. Sharp Reality and Unsharp Reality

As mentioned above, in the SI, physical system has two modes of reality, one mode is *unsharp* and the other is determinate or *sharp*. What we measure as a sentient observer is its determinate feature, which *appears* to the mind as a sharp reality, and what acts in nature without the contribution of mind is the *unsharp* reality. For example, $+1/2$ and $-1/2$ in z direction at every moment are sharp reality of spin of electron. In this sense, spin exist in sharp or determinate mode of reality. On the contrary, different states in the superposition correspond to different values but in a *potential* and *indistinguishable* way. So, spin has another kind of reality which is *unsharp*. It has both $+1/2$ and $-1/2$ values, but in a *brief* an *indistinguishable* and of course *flowing* way.

So, according to the SI, *superposition state* of a flowing object refers to a *genuine, simple* and *unified* reality. We should *not* think of it as representing the *sum of* or *real mixture* of multitudes of individual realities attached together. This explains why, in QM, we ought to differentiate between *superposition states* and *mixed states*, to distinguish between *proper mixture* and *improper mixture*². Although, the superposition is a reality, which is genuine and simple, it does *potentially, indistinguishably, and briefly* include parts other than what has been determinately observed by the observer. It follows that the reality of the superposition does not imply a mere *multiplicity* and *plurality* to end up with the difficulty of how an object could be *simultaneously* in multiple exclusive states.

Moreover, superposition state is a more complete description of reality than what is given by our observation and measurements as a determinate outcome, and as what appears to us as mental reality. Superposition states description of physical reality is a description of higher order or by considering a higher dimension as regards the determinate observed outcomes. This matter, accordingly, leads us to the conclusion that the reality of superposition state and indistinguishable reality should be considered as the *origin* of determination and definiteness of outcomes of measured quantities, *not as denying* it. If we were to consider the unsharp reality from the lower dimension, then it would appear to us as a determinate outcome; it would appear as *specific, definite, or distinguishable*.³ but if we were to consider it from higher dimension, the ‘superposition’, would be *superposition!*

¹ This *wholeness* in Bohm's model, that is the fact that “... not only the inter-relationships of the parts, but also their very existence is seen to flow out of the law of the whole.” (1971:viii), is explained by dependency of quantum potential on the state of the whole system.

² Disregarding this distinction leads to some confusions, when considering *decoherence* model as a solution for measurement problem. Bell (1990:25) raised this objection in this way: “The idea that elimination of coherence, in some way or other, implies the replacement of 'and' by 'or', is a very common one among solvers of the 'measurement problem'. It has always puzzled me.”; see also: Maudlin (1995:10).

³ Attempts to suggest new interpretations show that we have to *extend* our ontology and provide new *conceptual schemes* to understand the measurement process in QM. In Everett-like interpretations, this extension appears as additional worlds or minds, and in Bohm's model it appears as additional variables and a new potential with

Since superposition states are considered for *certain* observable and quantity, they are written in *certain* basis of space¹. These are superposition of pure states, each of which corresponds to specific values of the relevant observable. As for the pyramid and triangle picture, there is an ancestral relation between pure states and the superposition, which they make. This relation, since it has an ontological meaning in SI, explains how we encounter the *two modes of realization of the same* physical quantity; and they are represented in the *same* space.

Denying the reality of the superposition states originates from the presupposition that systems could only be *determinately* and *definitely* realized. But there is no compelling reason for this presupposition. We could consider systems as *four-dimensional* objects, though indeterminate from the four dimensional point of view, which *is appeared* determinate in three dimensional standpoint. This does not mean that unsharp reality, in its totality, exists at every moment of its lifespan. Since the total continuum of the unsharp observable, corresponding to the superposition state, does not realized at every moment (it is a flowing reality), *it is not possible* at all, for the observer, to see the whole continuum of *unsharp observable at a “moment”*, but he sees its total continuum in its total lifetime.² The determinate value we see for an observable quantity, at every moment, is only a hypothetical cross-section of the flowing continuum of the unsharp observable corresponding to the superposition state. In other words, the observer is right in describing and reporting his experience, but he is wrong in *interpreting* his determinate experience as the *ultimate* and *complete* reality.³ From the atemporal observer's point of view, or based on the quantum description of reality, system is not in a determinate state but it is in a superposition of states.

some weird properties. In Bohm's model, which denies superposition states, *quantum potential* is responsible for all of those strange behaviors which result from superposition states (Riggs 2009:127).

¹ Furthermore, while Dirac developed the general principles of quantum theory, he gave no *preferred* role to picturing processes explicitly as occurring in *space*, the democratic equality between different points of view was maintained in the new dynamics that resulted. All observables, and their corresponding eigenstates, had equal status as far as fundamental theory was concerned. The physicists express this conviction by saying that there is no 'preferred basis' (a special set of states, corresponding to a special set of observables, that are of unique significance). Wrestling with the measurement problem raised in the minds of some *the problem of preferred basis*. But, in the SI, this is by no means a fundamental necessity. Because of the continuous *total* renewal of the object, at every moment of time, and since our object, renewed with *all of its properties*, consistent with Dirac's formulation, there is no need to an *objective* preferred basis. The *so-called* preferred basis is as a result of what we (as observer) *prefer* to choose for measurement.

² While there is no plausible account for *unobservability* of Everett's branches (or other worlds in many-worlds interpretation) (Barrett 1999:158-9), there is an explanation for *unobservability* of all states or outcomes at *a moment*: all physical systems and entities are in correspondent with *continuum of time*, and because of the flowing nature of them, as in the stage theory, they persist through time by *perduring, not enduring*. I used the term 'perdure' to hold the basic idea that persistence is much like spatial extension. These systems, therefore, are four-dimensional objects with temporal parts, but we experience only a brief temporal parts or 'stages' of those four-dimensional objects.

³ Comparing with the bare theory makes this more clear. According to the bare theory, when a system is in superposition state, the observer would *falsely* report that he got some determinate result, because, as a matter of fact, there is no determinate state (Barrett 1999:96). But according to the Sigma interpretation, the observer has really a determinate experience, he *mistakes* when he thinks what he observes at every moment is *the whole* of the system.

4.2. A Critique Against the existence of Superposition

One might raise the objection that since the pointer of measuring device is quite a classical object, and different values obtained in measurement are macroscopically *distinguishable*, it makes no sense to say that it has no definite position at any instant of time.¹ This sort of objection considers a relation between *distinguishable* values of a quantity and its *reality*. In the SI, however, it should be emphasized again, there is no distinguishable position for the system before the measurement, and one cannot deduce *nonexistence* from *indistinguishability*.

To be more intuitive, consider the real numbers axis, which consists of numbers, *innumerably* and *indistinguishably*, ordered along the axis. This does not mean they do not exist. They exist, but *not* in a distinguishable way. Here we emphasize again that the meaning of potentiality of states in a superposition state is not that system, at the present, has no specific, and definite state, and could have it, rather it means the system *indistinguishably* takes the values corresponding to those states, just as real numbers axis, which is real and genuine, *innumerably* and *indistinguishably* includes numbers. When it is said that numbers *indistinguishably* and *innumerably* exist, it does not mean that the axis is devoid of any numbers. It *innumerably* consists of all numbers. It is possible to distinguish and specify a definite number in the real numbers axis only through cutting the real numbers continuum. In the same vein, only by cutting the superposition state, i.e. by *doing* measurement on the system, which is in superposition state, we could reach to a determinate and distinguishable state. Consequently, a determinate outcome corresponding to the pure state for the relevant observable could be obtained.

One might object that individuality is based on *definiteness* and *distinguishability* from others. When we accept that a system is in a superposition state and is not distinguishably in any parts of the superposition, and when we accept that its definiteness and determination can only be reached through cutting the superposition in hypothetical moments or points of time, it follows that those parts of superposition are ‘hypothetical’ and ‘unreal’. That is, system lacks any values for the quantity. In other words, it seems, since before measurement, the system is in a superposition state, it lacks any definite value for that quantity, which, in turn, corroborates Heisenberg's assertion: there is *no* observable *before* a measurement². This is the same conclusion which Einstein, rightly but based on a certain metaphysical framework, refused to accept by asking the question: do you mean when you do not look at the moon it does not exist?!

A system in superposition state, before a measurement, *actually* has values for the relevant observables but it should be noted that these “*actual*” values or individuals are for the flowing and persisting observable quantity stretches out four-dimensionally through

¹ See Ballentine (1970:368-9) for this objection.

² Heisenberg's famous dictum in his (1927) *Uncertainty Principle Paper* was that “I believe that the existence of the classical "path" can be pregnantly formulated as follows: The "path" comes into existence only when we observe it.”

time. The above objection had some force if the assumption to the effect that there is no observable before measurement would be plausible. But in the light of our account and by taking quantities of system as *flowing* properties, then the system undoubtedly consists of values for the observables.

5. Problems of Statistics

Quantum Mechanical predictions are probabilistic, based on the Born's rule. The usual application of Born's rule says that the outcome of an experiment is not determined, and there is, in fact, a certain chance of getting a possible outcome. One might ask, how is it possible that the *complete* wave function always evolves in accord with a *deterministic* dynamical equation (i.e.. the Schrodinger equation), but in measurement situations which are described by *identical* initial wave functions, measurement sometimes yields *different* outcomes, and the probability of each possible outcome is given (at least approximately) by Born's rule?

To account for the problem of statistics, consider the case of pyramid, plane and flatlander again. Suppose further that the pyramid has been colored in black and white. These colors are *exclusively* and *randomly* distributed in the pyramids so that cutting every cross-section of it, gives us a black or white cross-section. Though randomly distributed, we could see, in sum, half-length of pyramid is white and half in black. Therefore, if we cut a cross-section of it, there is a half chance of getting white and half chance of getting black.

What does the flatlander observe in the plane? Since he does not know of the third dimension, he observes a triangle, which *randomly* becomes black and white. But if this pyramid passes through the plane, times and again, he could eventually reach to the conclusion that, in sum or a in long run, the triangle, half of its lifetime becomes white and half of its lifetime becomes black.

On the other hand, for the external observer, there is no *real* triangle. But there are triangles which are cross-sections of a pyramid colored in black and white with a specific distribution. It *appears* to the flatlander that there is a triangle becoming white and black. Moreover, for the external observer, the pyramid, in its totality, is neither black nor white, and only after cutting the pyramid we could say the cross section is white or black. So flatlander's mind randomly, but based on a *specific distribution*, experiences a specific and determinate color. The evolution of the flowing object wave function, or in Everett's words the evolution of global wave function, is causal and deterministic. But, since the observer's mind experiences the *randomly becoming* black and white stages of the flowing object, based on a specific distribution, so the evolution of flatlander's *mental state*, is probabilistic and random. Accordingly, like Everett's model in the SI, although wave mechanics (Schrodinger equation) is deterministic, it gives rise to probabilistic appearances at the *mental level*, in such a way that the relative frequency of determinate outcomes is square of coefficients of superposition elements (Everett 1973:78), (Barrett 1999:79-81). But while there is *no explanation*, in Everett's theory, to account for why the observer has such mental experiences, in the SI there is an intelligible account for it.

The SI accepts the commonsense and intuitive idea that no individual system actually could be in different states at *a* moment, but it is possible to be in different states at *different* moments. Wave functions, in this interpretation, describe a flowing system that evolves according to Schrödinger equation. The system has a mode of existence or is in a state of affairs, known as the *superposition*, which originates from the fact that the system does not persist by enduring through time, i.e. it is not *wholly* present at every moments of time at which it exists.

These renewals, as in the statistical interpretation, are governed by Born's rule. We use the *ensemble* concept to define the probabilities because attributing the probability to every new state of happenings has conceptual difficulties. The technical reason is the same as in statistical mechanics; As Albert (2000:63) put it:

“it has to do with the fact that the sort of information we can actually *have* about physical systems—the sort that we can *get* (that is) by *measuring*—is invariably compatible with a *continuous infinity* of the system’s *microconditions*. This follows from the fact that the totality of the possible microconditions of any Newtonian system invariably has the cardinality of the continuum, and that the accuracies of the measurements that we are able to perform are invariably *infinite*. But the only way of assigning equal probability to all of those conditions at the time in question will be by assigning each and every one of them the probability *zero*. And *that* will of course tell us *nothing whatsoever* about how to make our *predictions*.”¹

The dispersion of measuring device pointer, in the SI, expresses possible measurement outcomes, and as far as the observation is concerned, there is no difference between the Sigma and the statistical interpretation in this regard. *Experimentally*, it makes no difference whether to say, we have a flowing system which has continual renewals with a specific distribution, or to say we have different systems, which are similarly prepared, and when we measure them, we would find a specific distribution for positions. The difference lies at the *ontological level*.

The statistical interpretation of the state vector could not be considered as a description of *individual* system. Ballentine rightly maintains that it makes no sense to say, that pointer of a macroscopic system has not a determinate position (Ballentine 1970:371). However, it makes no sense in a *specific metaphysical framework*, and it might be possible and meaningful in a different metaphysical framework.

Contrary to the ontology of statistical interpretation, as we consider quantum systems as flowing and four-dimensional objects, SI takes dispersion as a property of the individual systems. These objects do not persist by enduring through time. That is, the system could not *distinguishably* have all of the possibilities, and could not *distinguishably* take all the possible positions *at a moment*, rather the quantum systems *indistinguishably* and *potentially* takes all those possibilities, the quantum objects persist four-dimensionally through time, and the observer's measurement *mentally* creates a *distinguishable* determinate position for him.

¹ Since these renewals are happening at every moment so they are superluminal but relativity governs on ensembles of them. Compare this with what Bohm said: at the underlying level there could be nonlocal behavior but at the ordinary level, we experience covariant behavior (Bohm & Hiley 1993:286).

Everett also makes a difference between mental state and physical state evolution. While he takes the latter as a deterministic process, he takes the first, i.e. mental state evolution, as a probabilistic process. In the SI, likewise, if distribution of renewal at t_0 is $|\Psi(t_0)|^2$, then Schrodinger equation *deterministically* gives us the distribution $|\Psi(t)|^2$. But system's renewals at every moment happen, at best, according to the statistical distribution and accordingly we could attribute a probability to the ensemble.¹

In the Sigma model the physical state of the flowing quantum object always evolves in the usual *linear* way, but in order to have a complete theory, we also need to specify an *auxiliary dynamic*. Perhaps the simplest dynamics would be one like the configuration dynamics in Bell's Everett theory, where the probability of observer's current mental state is fully determined by the current physical state alone and is always equal to the norm-squared of the component of the universal state that describes observer as currently believing the corresponding determinate outcome.² The Sigma interpretation with the completely random stage dynamics, which were discussed above, would convert to something like Bell's Everett theory. The continuous and random renewal of temporal parts of the flowing system makes observer's mental state to jump randomly regardless of its last state.

In the Sigma model, the observer's mind, as in the single-mind or many-minds theory, is not a quantum mechanical system; it is never in superposition. This is what is meant by saying that it is non-physical. The time evolution of observer's mind in the Sigma interpretation is, just as in the many-minds or single mind theory, probabilistic. Furthermore, although the evolution of individual stages or renewals is probabilistic, the evolution of the set of stages associated with a flowing quantum object is deterministic, since the evolution of the measurement process is deterministic and we can read off from the final state the density of the stages in various states.

Evolution of flowing systems, in the Sigma interpretation, is both causal and stochastic. From the observer's point of view, it is stochastic, but the probabilistic feature is *not inherent* in nature, rather it originates from specific statistical distribution of renewal of stages of the flowing system. This indeterminism is not necessarily a sign of intrinsic chances in nature. Rather it means objects involve continuous renewal with a specific distribution. Of course, we should pursue a plausible account for this distribution. This is close to the Bohm's interpretation. We have an *implicit* order, which is the source of *explicit* order. The observer, who does not see all dimensions, only sees a determinate outcome and, at this level, he could describe all what he sees but could not give an intelligible account for it.

The interpretation which takes the statistical predictions of quantum mechanics as the result of our ignorance, the so called *ignorance interpretation*, is not consistent with the real superposition states and empirical outcome of quantum mechanics (Auletta 2000: 107-115). In the SI, likewise, we could not adhere to the ignorant interpretation of probabilities, since

¹ In Sigma interpretation, contrary to Everett's theory, *the whole* system does not exist *at a moment*. It has temporal parts and its whole reality can be found at the whole lifetime of system.

² This is similar to the single-mind analogue of the evolution of position in Bell's Everett theory. See (Bell 1987:133) and (Barrett 1999:187)

that specific distribution is part and parcel of the *flowing* system. Despite this fact, pursuing hidden variables for individual events is not only warranted, but also recommended. Bohm, in his later works, took the stochastic feature irreducible *not* in the sense that there is no causality. There could be hidden variables at deeper levels.¹ He maintained that "... the chaotic or stochastic character may be contingent and determined by conditions in domains not covered by the particular theory in question. For example, random variations in the trajectory of a Brownian particle may be partially or even totally determined by atomic motions at a deeper level. So ultimately our overall world view is *neither absolutely deterministic, nor absolutely indeterministic*. Rather it implies that these two extremes are abstractions, which constitute *different views or aspects of the overall set of appearances*. Which view is appropriate in a given case will depend both on the *unknown totality* and on *our particular mode of contact with it* (e.g. the kinds of experiments we are able to do)." (Bohm & Hiley 1993: 324; *italics are mine*).

So, we can and should still raise the question *why* such a distribution governs these renewals. We need an independent justification, other than adequacy of quantum mechanics, to account for this distribution, and this is not a problem specific to the SI alone; Bohm's and Everett's model also have such a postulate and should give a plausible account for it.

6. Problem of Effect

Consider an electron with positive x-spin enters a device with z-spin measuring device. The outgoing electron has a z-up spin or z-down spin. Repeatability condition requires if the first measurement outcome is up, then the result of the second measurement, which is *immediately* done, also certainly and definitely ought to be up. This is known as the *problem of effect*.

These considerations make "plausible" (but of course are not intended to 'prove') one of the postulates of standard quantum mechanics, which tells us how the state vector is affected by a measurement: A measurement of an observable generally causes a drastic, uncontrollable alteration in the state vector of the system; specifically, regardless of the form of the state vector just before the measurement, immediately after the measurement it will coincide with the eigenvector corresponding to the eigenvalue obtained in the measurement.

Ballentine criticized Dirac (1958, 36) for taking such a condition seriously. He maintained that expecting the second measurement of the same observable, immediately after the first measurement, to yield the same result of the first measurement

"... is true at most for the very special class of measurements that do not change the quantity being measured. A statement of such a limited applicability is hardly suitable to play any fundamental role in foundations of quantum theory. In fact this argument is based on the implicit (and incorrect) assumption that *measurement* is equivalent to *state preparation*, For example, a Polaroid filter placed in the path of a photon beam constitute a *state preparation* with respect to the polarization of any transmitted photons. A second Polaroid at the same angle has no further effect. But neither of these processes constitutes a *measurement*. To measure the polarization of a photon one must also detect

¹ This is similar to Ballentine's statistical interpretation. See (Ballentine 1970:380), (Auletta 2000:106).

whether or not the photon was transmitted through the Polaroid filter. Since the detector will absorb the photon, no second measurement is possible.” (Ballentine 1970:369).

This argument, however, seems to be inconclusive. Consider an x-spin measurement on a y-spin up electron. In any theory, this measurement will change the quantity being measured: before the measurement, in the standard interpretation, the electron does not have an x-spin. But *immediately* repeating the measurement will certainly give the same result. The absorption of the particle in certain measurement techniques is incidental, and one could imagine ways of carrying out the measurement that does not do this. The predictions of the theory for the measurement outcome would not be changed. There are classes of measurements, associated with projection operators, for which repeating the measurement immediately will certainly give the same result. There will be correlations between successive results, which is another way to have the problem of effect. So, as Maudlin said:

“The result of a measurement therefore has predictive power for the future: after the first measurement is completed we are in a position to know more about the outcome of the second than we could before the first measurement was made. Any theory which seeks to replicate the empirical content of the traditional theory should have this feature.” (1995:13).

Similarly, Bell, in a critical assessment of Everett theory, pointed out that Everett's model, like Bohm's, should suggest a dynamics to preserve the *reliability* and to yield the previous result in repeating measurements (Bell 1964:133, 135-6), (Barrett 1999:80, 124-6,185).

But what about the Sigma model? What does the observer *actually* measure? According to the Sigma model, the probability of the actual outcome ending up associated with a particular term in the quantum-mechanical state is completely determined by the current quantum-mechanical state and is independent of past outcomes. It is given by the square of the coefficients of the terms when the wave function is written in the related basis.

The system, in this interpretation, is in perpetual renewal. These renewals could happen in a way completely similar to the previous one, and from the empirical observation and observer's standpoint, *it is like saying that* the same value has been obtained. This situation, however, cannot be sufficient to solve the problem of effect. It would be typically possible that the observer's immediate measurement, in fact, would lead to wildly different outcomes. This situation is similar to the Bell's Everett(?) theory. As Bell put it:

in our interpretation of the Everett theory there is no association of the particular present with any particular past. And the essential claim is that this does not matter at all. For we have no access to the past. We have only our 'memories' and 'records'. But these memories and records are in fact present phenomena. The theory should account for the present correlations between these present phenomena. And in this respect we have seen it to agree with ordinary quantum mechanics, in so far as the latter is unambiguous. (Bell 1987: 135-6)

Bell objected that “if such a theory were taken seriously it would hardly be possible to take anything else seriously” (1987: 136; see also 1987: 98). The same is true for the SI. While, generally and typically, it is in agreement with the statistics of standard theory, there is no guarantee that there would be a correlation between the present subjective result and later or former mental result.¹ Accordingly, Sigma theory, Just as Everett-like theories, needs an explicit rule to connect states at different times (Barrett 1999:197-198), and without such an explicit auxiliary dynamics the Sigma theory seems to be incomplete. This auxiliary dynamics, which can be obtained as Bohm’s approach for particle path equation, is to describe how the determinate local stages (temporal parts of the quantum object) evolve, while the universal wave function is evolving in its usual linear way.²

7. Conclusion

Every rational theory, whether scientific or philosophical, is rational in so far as it tries to *solve certain problems*.³ In this line of thought, we attempted to show that the Sigma interpretation, as a theoretical proposal for the measurement problem, is *as reasonable and rational as* rival theories to give an account of the measurement problem, by assessing its ability and capacity to solve the three measurement problems, i.e. the problem of outcome, problem of statistics and problem of effects.

The SI is an attempt to show, if we want to be *realist* about quantum theory, if we want to accept the entities and states of the theory as *real*, we need to suggest new conceptual schemes, but *neither* in an isolated way nor in an ad-hoc manner. It suggests, by taking superposition state as *real*, a new conceptual framework; or in Bohm's word, a “new order” for our universe (Bohm 1980:175). In spite of some similarities, SI, by taking *four-dimensionalism metaphysics*, is sufficiently differentiated from other interpretations.

Sigma, like Everett-like and Bohm’s model, has an advantage over the standard interpretation. All of them, unlike standard interpretation, are completely explicit about what really exists and how they evolve. There is no shifty division between the macro and micro worlds. There are also some more advantages: First, unlike the bare theory⁴, Sigma is in accord with our very deep conviction that mental states never superpose. Nonetheless, it remains true to Everett's fundamental idea that the time evolution of the entire universe and every *physical* system is given by the linear dynamics: There is no need to postulate collapses or splits or any other non-quantum mechanical physical phenomena. The reason that ‘physical’ is emphasized here, is that Sigma, like many-minds theory, supposes the existence

¹ It seems that all subjective interpretations, even von Neumann's own interpretation, which takes collapse as a subjective process, involves such a difficulty.

² Stage dynamics, in the Sigma, is on a par with mental states in the many-minds interpretation, as Albert said “What's been said so far ... doesn't amount to a completely general set of laws of the evolution of mental states; but laws like that can be cooked up, and they can be cooked up in such a way as to guarantee that everything I've said about them so far will be true.”(1992:129)

³ This doctrine has been mainly developed by Popper. See for example, Popper (1958).

⁴ See Barrett (1999:194)

of a nonphysical entity, namely the observer's mind, whose states are not determined by the global quantum-mechanical state of the flowing object, and it makes possible the self-consciousness of the observer to his trans-temporal identity. Sigma theory also provides a particularly natural way to make sense of the claim that, at the end of a typical measurement, while in one sense there is only one physical observer and one physical system, in another sense there are many *potentialities* with mutually incompatible experiences. But, contrary to many-minds theory, there is no need, in the SI, to consider *continuous infinite minds* for the observer, and to encounter difficulties in interpreting what it means to have many minds and how it is possible to have these minds, while all belongs to an *individual* observer, *without* any connection between them. There is no more than one mind in the SI, but this mind encounters continuous and infinite renewals of the system. Moreover, because of the *reality* and genuine nature of superposition states, Sigma model, has no problem concerning *personal identity*.

Everett gives no explanation for the total lack of influence of one branch on another. He, it seems, takes it for granted to explain why one would not feel the branching process. The same is true for *unobservability* of the splitting of universe in many-worlds theory. In the Sigma theory, however, there is an account for it: none of the two temporal parts of a *flowing* object (a four-dimensional object), as a *flowing continuum*, like time, exists together. Moreover, taking this model seriously, leads us to the conclusion that quantum theory shows yet another limitation of our perceptual experience, i.e. our inability to perceive *unsharp reality*.¹

Despite these advantages, the four-dimensionalism proposed in the SI, may still provoke “incredulous stares”! We cannot consider the type of relation of mental state to physical state that Sigma theory provides as *supervenience* in a usual sense.² If we accept mental supervenience, we might want the mental state to supervene on physical state. But based on the Sigma theory, the observer is associated with an infinite set of stages that most likely are associated with wildly contradictory beliefs and whose mental states the observer cannot know at a single moment. Although, the fact that the observer is associated with a continuous infinity of stages is at least counter-intuitive, this theory is not so counter-intuitive as many-minds which associates each observer with an *infinity of minds*. But, though we have mentioned some advantages and positive arguments in favor of SI, there is no *advantage claim* at this stage. The claim of the paper, as mentioned in the abstract, is modest: SI is as *rationally plausible* as its rivals and deserves to be criticized.

¹ It is a virtue for a scientific or philosophical theory to specify, in some ways, the *limitations* of our knowledge. Relativity shows our limitations in accessing information outside of the light cone. Godel's theorem specifies limitations of certain axiomatic systems. Kant's theory of knowledge attempted to show limitations of reasonable knowledge. All of these theories, regardless of their plausibility, specify, in some ways, limitations of our knowledge.

² The Sigma interpretation is *not* unique concerning *supervenience*. We encounter similar situation in von Neumann's interpretation (Becker 2004:127), and Bohm's theory (Pylkkanen 2007:192). It is also worth mentioning that *mind-body dualism* is not specific to SI. The many-minds and von Neumann Interpretation have the same presupposition of dualism. Moreover, since a clear account of mind/body interaction concerns the general mind/body problem, so this is not a problem that this paper aims to tackle with.

Finally, as Sklar (1974:2) and Balashov (1999) put it, there is an interdependence between science and philosophy. It is not simply that one cannot do good philosophy without relying upon the results of scientific theorizing. Although Science constantly forces us to revise and tame our commonsense and intuition, the acceptance or rejection of particular scientific theories depends as much upon the adoption of philosophical presuppositions as it does upon the evidence of observation and experimentation. The measurement problem is sometimes portrayed as merely philosophical, or of no interest to physics proper. This, as Maudlin (1995) said, is quite untrue. Each model carries with itself an obligation, which demands the postulation of *new physics*.

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