# SUB-ATOMIC PARTICLES AND SCIENTIFIC POSITS

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ABSTRACT

This paper is divided into two parts. In the first part an exposition is given of the way two purpotedly different views of nature (classical Newtonian physics concerning matter, and electrostatic laws concerning charges) were fused into one theory (Quantum Physics) concerning the ultimate constituent elements of nature (whether of matter or of electrostatic forces). An account is given of the epistemic dimensions associated with such a fusion, and especially of the well-known "Uncertainty Principle". In the second part of the paper these epistemic elements are further exposed. Through their exposition a theory is developed concerning "scientific posits": The inability to focus on the object under study through a simultaneious characterization of its properties on the one hand, and the inevitable changes that occur to the object's properties through a characterization of any of those properties on the other hand are both factors that give rise to the notion that a paradigmatic scientific object is in fact a *set* of discrete instances and it is, in this sense, a posit par excellence.

Ever since the development of Quantum Theory, many questions have been asked as to the philosophical interpretation of such a theory and its transitional effect on the understanding of modern science. The pillars of Quantum Theory include scholars such as Max Planck, Niels Böhr, Erwin Schroedinger, P A M Dirac, Werner Heisenberg and J. von Neumann. In a sense, Quantum Theory is one extreme of the behaviour of inanimate objects and together with the Theory of Relativity (as developed by Albert Einstein) stands out as a challenge to modern philosophy and science. It is instructive at this stage to note that both theories are connected with constants; Planck's constant which is a very small number is connected with Quantum Theory, and the speed of light which is rather a large number is associated with the Theory of Relativity. One would therefore argue that had Planck's constant been zero and had the speed of light been infinite, these two theories would not have been of much practical or philosophical importance. It seems, therefore, that Nature is limited by these constants in a manner that would make it impossible for us to know absolute reality. Although the non-existence of Planck's constant would have relieved one extreme, the other extreme would have lead to a different conception of determinism had one assumed an infinite speed of light. The classical laws of Newton are related to objects termed "particles". These particles can be absolutely and accurately described by measurement of certain properties such as their position and their momentum at a given time. In classical physics, a phenomenon or event purportedly related to a given object may be observed without disturbing the object in question.(1) Moreover, the concept of causality allows one to be able to describe all the dynamical variables purporting to a given object deterministically in time. These dynamical variables are completely detached



from the measuring apparatus in the sense that they cannot be subject to change by the mere fact that one is attempting to make a measurement of them. This leads to the statement that the objects and the means of observation are mutually exclusive entities.

In addition to Newtonian laws, there seemed a necessity to introduce a new set of laws in order to deal with electrostatic force fields and electrostatic forces that act from a distance. These laws could be best quantified by wave theories. One would thus classify electrostatic and electromagnetic theories under this general category. The laws governing these theories were developed by James Maxwell. These two disciplines (i.e. Newtonian Mechanics and Maxwellian Electrodynamics) would seem to be able to describe all natural phenomena. However, an iminent question to ask was how would a wave (i.e. electromagnetic radiation) travel in space before it interacts with matter (i.e. particles)? The answer to this intriguing question was solved by proposing the existence of an artefact; ether. One would thus argue that this etherial material was responsible for the compatibility of the otherwise mutually exclusive theories.(2) It became apparent, however, towards the turn of the century that the artefactual hypothesis needed to be reviewed since it was evident that such a hypothesis was an unnecessary imposition. Within that period, scientists started realizing that Newtonian laws were not applicable for particles of small mass such as electrons Schroedinger made the bald step of assuming that the equations that govern electrons under a set of known conditions can best be described by wave rather than particle mechanics.(3) Niels Böhr and Werner Heisenberg attempted and succeeded in proposing an interpretation of these new ideas both philosophically and scientifically. To start with, it was suggested, one had to forget about the necessity for the compatibility of wave and particle mechanics. The two classical theories were thus assumed to be complimentary to each other.[4] Nature, in a sense, is much more complicated than one would like it to be and with the limited capacity of the thinking power of man-kind, it seems as though it would be difficult, if not impossible, to introduce one fully comprehensive consistent theory to explain the behaviour of particles under every condition. Quantum Theory was thus conceived. It starts by assuming that a particle of sub-atomic dimension, subject to a given electrostatic or gravitational field, can best be described by a function, known as a wavefunction. This function has the property that when one squares it, one obtains the probability that the particle exists in a given space element at a given time. Associated with each observable, one hy-thesizes the existence of a mathematical operator. This operator would thus project, or generate, from the wavefunction the values associated with that particular observable. For instance if H (henceforth known as the Hamiltonian) represents the operator associated with the total energy of a system (whose potential is taken to be spherically symmetrical), then one writes:

$$H \psi = E \psi$$

where E is the total energy of the system. Such an equation is known as an eigenvalue equation; $\psi$ is the eigenfunction and E is the eigenvalue. It will be interesting to note that, for the above-mentioned case, both the position and the angular momentum operators do not form an eigenvalue equation with the wavefunction and hence both cannot be treated as 'observables' in the eigenvalue sense. The best that we can get out of these 'observables' is to



define their expectation values. These are defined using the Dirac notation:[5]

$$< a > = < \psi | a_{op} | \psi >$$

where the lefthand side of the equation represents the expectation value of the 'observable' $a$, $a_{op}$ represents the operator associated with the 'observable' $a$ and the brackets that appear on the righthand side of the equation represent the integral of whatever appears inside the bracket throughout space. Thus contrary to classical predictions, and subject to the condition that the operator characterizing the momentum (or the position) of any physical system does not form an eigenvalue equation with the wavefunction,[6] it will be impossible to define the position and/or the momentum of a particle with arbitrary accuracy.[7,8,9] Or, alternatively, although it might be possible to characterize the exact position of a particle (provided that the operator characterizing the position of the particle forms an eigenvalue equation with the wavefunction), a heavy price would have to be paid: complete ignorance of the momentum of that same particle. Moreover, in an attempt to define with arbitrary accuracy the position and the momentum of the particle simultaneous-ly allowing for a decrease in the uncertainty of the one, ultimately leads to an increase in the uncertainty of the other.[10,11,12] This came to be known as the Uncertainty Principle. This Principle exhibits itself very strongly not as a result of the impossibility of envisaging an apparatus that would simultaneously measure the position and the momentum of a particle with ar-bitrary accuracy, but rather as a result of a Creed of Nature that renders the construction of such an apparatus impossible.

It was previously indicated that the Hamiltonian of a system generates from the wavefunction the total energy of the system. This is true in as far as the system is taken to be time independent. If one were to include the dimensionality of time, however, an Uncertainty relationship ensues between the time and the energy. Although it might be proper here to assume that any operator that commutes with the Hamiltonian of the system is associated with a measurable observable, yet such a statement cannot be passed without further elucidation. For instance in the theory of the Hydrogen atom, the square of the angular momentum operator commutes with the Hamiltonian, but this does not necessarily mean that the angular momentum can be treated as a measurable observable. The fact is that the square of the angular momentum operator and each of the components of the angular momentum operator commute (or almost commute) with the Hamiltonian but the components of the angular momentum operator do not commute amongst each other. This leads to the conclusion that the total energy, the *norm* of the angular momentum and one of its components can be treated as measurable observables.[13] These observables are actually quantized in nature and only certain discrete states (known as quantum states) can be actually defined; contrariwise to classical physics where the dynamical variables associated with a given particle are assumed to be contained in the continuum.

We are now ready to commit the logical fallacy of *Pettitio Principii*. A phenomenon we have argued is to be taken in conjunction with the changes that occur to the dynamical variables of the object under study. But a pre-condition for characterizing these changes is the means of observation. However, quantum mechanics *allows* for the interaction of the object with the apparatus. This ultimately leads to the exposition that the object in question can not be treated independently of the means of observation. In otherwords, the apparatus is actually part of the phenomenon. A phenomenon, therefore, would have to be resolved into a threesome: the object, the interaction and the apparatus.[14] What then happens to the object as it interacts with the apparatus? Does the object change? Does it change its quantum state? Is the conscious observer part of the phenomenon? Is the object itself and not itself at the same time? A paradox of unimaginable complexity.



We pause here to elaborate on an epistomological question. The apparatus is limited, by virtue of its construction, to measure classical dynamical variables; but the (quantal) changes that occur to the object under study can in no way be explained in terms of classical physics. We are thus faced with a problem: either we have to accept an indeterminacy in studying the *classical* dynamical variables of the object under study, or we have to devise a quantum mechanical apparatus that would make it possible for us to describe the dynamical variables of a *quantal* phenomenon with arbitrary accuracy. Perhaps Heisenberg puts it better. He writes: "If there were experiments that permitted accurate measurement of all the characteristics of an atomic system necessary to calculate classical motion and which for example supplied accurate values for the location and velocity of each electron in the system at a particular time, the results of these experiments could not be utilized at all in the formalism, rather it would directly contradict the formalism".[10] Notice that throughout these arguments we are making a distinction (logically at least) between an object on the one hand, and the variables or properties or states which characterize that object on the other hand. Even when we hypothisize that there may be fusion between object, apparatus and property or state we tend to assume that such a fusion is between already distinct and unique entities. But in what sense is an object, say a sub-atomic particle really a distinct and unique entity? We are constrained here by epistemic considerations to raise a more fundamental question concerning the ontic status of such objects. Because, say we wished to identify a sub-atomic particle such as an electron: in order to proceed with such an identification it is necessary to characterize that particle's properties. However, the Uncertainty Principle does not allow us to measure simultaneously such properties of that particle as its position and its momentum. Furthermore, however, the mere attempt at measuring any one such property influences the object in question by creating a change in some of its other properties. But by now our dilemma becomes obvious: on the one hand to postulate a particle as having a certain quantum state (or as being characterized by a certain set of descriptions) which is such that it undergoes a change through and as a result of its measurement is to postulate exactly what we aim to identify by means of this measurement (the fallacy of *Pettitio Principii*). But on the other hand to allow ourselves only the perspective of property-descriptions as a means of identifying an underlying object is to impose a restriction on our ability to identify such an object whether because such properties are constantly changing as a direct result of our attempts or because they cannot all be measured simultaneously. In this case, however, such epistemic restrictions give rise to ontic doubts concerning the uniqueness and distinctness of objects we fail to identify.



The ultimate puzzle, therefore, is to do with the status of scientific objects such as electrons. It is in addition clear that the problems facing us in trying to determine the answer to this question are the following two separate but related issues: first a scientific object of the kind we are considering is such it cannot simultaneously be characterized by particle and wavefunctions. This, notwithstanding the observation that in order to give a complete description of such an object it is apparently necessary to account for both kinds of characterizations. And second, a scientific object of the kind we are considering is also such that the mere attempt to characterize it by means of the properties it is assumed to have, introduces a change (at least) to some of them. However, because it is precisely by means of its properties that we set out to identify it, it becomes questionable whether it would be meaningful to posit such an object in the first place, or stated differently, it becomes questionable whether the set of descriptions we end up with can in fact be assumed to be descriptions of exactly that object we set out to identify in the first place. However, this last remark gives rise to an even more serious problem: because, if it can be shown that a purported set of complete descriptions is never one that defines just *one* object, or it is never one that succeeds in identifying that object it set out to identify, then it will be clear that a scientific object of the kind we are considering is such that it cannot non-simultaneously be characterized by particle and/or wave functions. Under such circumstances a dilemma will seem to be in the offing which may be formulated as follows: for any particle at all, it will be impossible to provide a complete description of its properties, simultaneously or otherwise; and conversely, for any set of descriptions, simultaneously provided or otherwise, such a set will not define or characterize a unique object. But taken one step further, *if* we assume that it is meaningless to posit a property as a property of an object when such a property is uncharacterizable or is not measurable, then the following can be concluded, namely, that scientific objects of the kind we are considering (i.e. objects to which such sets of descriptions are purportedly related) do not exist as primary individuals in the first place. In otherwords, such 'objects' are not unified individuals persisting through space-time, and surviving as objects with the same identity notwithstanding the changes that occur to them, but are or should be regarded as infinitely scattered instances no one of which, strictly speaking, is identical with the other.

We now come to our conclusion, namely, that when scientists or philosophers of science speak of scientific objects as *posits*, such formulations will be meaningful within the framework presented in this paper in the following way: a scientific object is a posit in the sense that it is a *set* of a certain number of scattered instances, and it is a heuristic device in so far as it represents an otherwise absent continuum in space-time of one unique individual (In this sense, an instance will also be a set of a set of a set ............)

Here it may be noted that the reason we did not speak of time dependence is that one needs to introduce a time dependent evolution operator in order to describe the evolution of a quantum state in time. The description of the energy of a given quantum state is related to the time evolution of that state; i.e. an uncertainty relationship pervades that set as well.



Having stated our conclusion, let us now look back briefly to two separate considerations that led us to it. These considerations were, first, that it is impossible to give a comprehensive set of descriptions for a unique object and, second, that a non-measurable property is in fact no property at all, and that, therefore, no object which is purportedly characterized by such a property exists.

With regard to the first consideration, it is arguable that if one begins with observations of phenomena with the purpose of identifying an object as one to which these phenomena are related as properties, then it will be impossible to identify any one object as an object to which a certain set of properties are related precisely because the very act of observation interferes in such a way as to render any one possible set and hence the object to which it is purportedly related as obsolescent. Because, assuming that our identification of an object is made simply and only on the basis of the possible characterization of its properties, then two successfully related sets of properties which differ from each other even only minutely will strictly speaking have to be construed as identifying two separate objects.

But given that the very attempt to formulate any such one possible set, in fact, is superceded by, or gives way to the formulation of the second set, then the object to which the first possible set is related will be different from the one to which the second is related. But this is not to say that the second set identifies an object at all. Because what is that object to which the second set is related? Actually it is no object at all but an abberation or a misfit created precisely by our shift in focus. Indeed, such a second set will in fact have to be a possible set with respect to the second object, because its formulation vis-a-vis the second object will give rise to and will be superceded by a third set with regard to the second object and will in turn be a mere abberation. There are then, two separate considerations to take account of in this context. There is, first, the statement that even if we succeed in providing a comprehensive set of properties, this comprehensive set will be different from the comprehensive set which it had perforce to supercede, and hence it will identify an object, if any at all, which is different from the one it set out to identify. And there is, second, the statement that the comprehensive set which is formulated will in fact be an abberation caused by a necessary shift in focus, such that it cannot be regarded as in fact identifying an object because with respect to any such object, this set will be self-obsolescent, giving rise to yet a third set. Together, these statements imply that no one set is in fact related to a primary individual. (It is also evident, from the Uncertainty Principle, that no such set which is formulated on the basis of simultaneous characterizations is possible either).

Before we pass on to the second of the two issues we used in arriving at our main conclusion, it is useful to state a possible objection to our line of thinking: it may be argued that one does not begin by observations of phenomena in order to identify an individual in the first place, but one posits this individual as a preliminary step to characterizing it. In such a case we will not have a problem with "disappearing" objects or individuals. But in order for this objection to make any sense, two other issues will have to be made sense of, one of which is the classical distinction between



essential and non-essential properties and the second of which is the ontic meaningfulness of making such a posit. However, with regard to a sub-atomic particle, say an electron, it makes even less sense to speak of a distinction between essential and non-essential properties than it does with regard to supra-atomic particles. Because which of the electron's properties are essential and why?

Secondly, however, what would it mean to 'posit' an electron as an object of discourse? If what is meant is that there is such an object existing independently of our discourse about it, then surely it is at least such that we can characterize it. But if we cannot, that is, if it is uncharacterizable, then it will not be clear what is meant by positing it as an object of discourse in the first place?

This final remark leads us to the second of the steps used in our argument: we said that a non-measurable property is no property at all. In other words, if it is impossible to characterize all the purported properties of an electron then the electron simply does not have them; but conversely, any purported comprehensive set of properties would not in fact and in any case identify a particular object.

The immediate problem of course is that we cannot provide simultaneously a set of descriptions which will at one and the same time account for the electron under every condition (for when it behaves as a wave and for when it behaves as a particle). But if it is impossible to provide such a set of descriptions for an object, this may well be because there is no such object with such descriptions in the first place. Speaking ontically, in other words, there simply may not be a persisting primary individual which is an electron which has these properties. In this case an electron, as a persisting primary individual, will be a posit par excellence, that is it will be simply a set of discrete objects or of instances, none of which is completely or comprehensively characterizable, or none of which, in other words possesses more than that property by which we identify it. In this case, a unique description will be exhaustive in the sense that not only will it pick out at most one object but that it will itself be at most a characterization of just one object. Such an outlook obviously implies a proliferation of entities, but it is, or may be precisely because of such proliferations that we settle heuristically for sets as individuals, perhaps in much the same way, obviously inappropriate but heuristic that we settle for idioms such as "It divides and divides again", or "Four is twice divisible by two" or even for singular terms such as "the Arab World".



## REFERENCES

1. Böhr, N., Proc. Phys. Soc., 78, 11083 (1962)
2. Messiah, A., *Quantum Mechanics* , North-Holland, Amsterdam (1961), p.4
3. Schroedinger, E., "The Fundamental View of Wave Mechanics", Nobel lecture, 1933, in Ghatak, A.K. and Lokanathan, S., *Quantum Mechanics* , The Macmillan Co. of India, Delhi (1975)
4. Davydov, S.S., *Quantum Mechanics* , 2nd Ed., Pergamon Press, Oxford (1965), p. 39
5. Dirac, P.A.M., *Quantum Mechanics* , 4th Ed., Oxford at the Clarendon Press (1958), p. 16
6. Dirac, P.A.M., *ibid*, p. 45
7. Landau, L.D. and Lifschitz, E.M., *Quantum Mechanics* , Pergamon Press, Oxford (1974), p. 42
8. Pilar, F., *Introductory Quantum Chemistry* , Mc-Graw Hill Book Co., New York (1968), p. 74
9. Böhr, N., Dialecta, 2, 312 (1948)
10. Heisenberg, W., "The Development of Quantum Mechanics", Nobel Lecture, 1933, in Ghatak, A.K. and Lokanathan, S., *Quantum Mechanics* , The Macmillan Book Co. of India, Delhi (1975)
11. Scheibe, E., *The Logical Analysis of Quantum Mechanics* , Pergamon Press, Oxford (1973), p. 35
12. Margenau, H., *Physics and Philosophy* , Episteme 6, Reidel Pub. Co., Dordrecht, Holland (1978), Ch. 2
13. Sobelman, I.I., *An Introduction to Atomic Spectra* , Pergamon Press, Oxford (1972), Ch. 1
14. Scheibe, E., *ibid*, p. 27