

DOES QUANTUM MECHANICS APPLY TO ONE OR MANY PARTICLES ? AN ALTERNATIVE AND MORE GENERAL VIEWPOINT

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ABSTRACT. A recent inquiry of the consistent application of Quantum Mechanics when dealing with spectroscopic transitions is re-examined in wider context. The statistical interpretation of Quantum Mechanics is discussed in relation to the more usual orthodox interpretation. The fundamentals of the Stochastic Electrodynamics theory are briefly described. The importance to know the several possible interpretations of Quantum Mechanics is stressed and some pedagogical consequences are pointed out.

RESUMEN. Se vuelve a examinar más ampliamente una reciente investigación sobre la aplicación de la mecánica cuántica con respecto a las transiciones espectroscópicas. Se discute la interpretación estadística de la mecánica cuántica en relación a la interpretación ortodoxa más común. Se describen brevemente los fundamentos de la teoría electrodinámica estocástica. Se enfatiza la importancia de conocer las diversas interpretaciones posibles de la mecánica cuántica y se señalan algunas consecuencias pedagógicas.

INTRODUCTION

Recently, Castaño et al¹ have inquired whether Quantum Mechanics (QM) applies to one or many particles when dealing with spectroscopic transitions. They analyzed the usual formulation of time-dependent perturbation theory to describe transitions and to find the system to which they refer. These authors found that some inconsistencies appear when the system is an isolated particle. As a conclusion, they stated that the time dependent Schrodinger equation is the most powerful tool.

The problem treated by Castaño et al¹ has a paramount importance since it is closely related to the foundations of QM.² It is surprising that standard textbooks on Quantum Chemistry (QC)³⁻⁵ do not deal with this basic aspect and those on QM only barely consider the point.⁶⁻⁸ In reality, the inquiry raised by Castaño et al may be inserted in a wider context and consequently, deeper questions can be asked and more general answers can be obtained.

The purpose of this paper is to display the so-called statistical interpretation of QM and to discuss its relationship with the more usual or orthodox interpretation. As it is indicated below, several interesting enough pedagogical consequences are derived and even some well-known QM paradoxes can be overcome via the statistical interpretation.

The structure of the paper is as follows. Section II deals with the statistical interpretation of QM. The next section is devoted to the specific point of spectroscopic transitions and the manner its proper explanation demands an statistical interpretation. In the last section it is discussed some consequences of the existence of several interpretations of QM, mentioning briefly the basis of the Stochastic Electrodynamics theory.

The statistical interpretation of Quantum-Mechanics

In order to introduce the statistical interpretation of QM recourse is taken of the classical phenomenon of electronic diffraction. It is unnecessary to repeat here the experimental details and the corresponding results because they are appropriately described in the usual textbooks on QM and QC.³⁻⁸ The proposal is to discuss the results in an alternative way to understand the physical facts. According to the current orthodox interpretation³⁻⁵ the phenomenon cannot be explained in a corpuscular language. Then, it is considered that this kind of experiment reveals in a plain manner the wave properties of the electrons.

When examining the experiment under a very weak electron density in such a way that just one electron impinges on the screen within a time interval large enough to register it individually,⁹⁻¹³ the careful observation shows that the appearing order of the luminous point is really chaotic. It is not possible to predict where a given electron will fall on the screen, given whatsoever information at disposal. In fact, even though all the electrons are fired in so similar and controlled conditions as possible, their final positions change hazarously from case to case. Then, one is led to conclude that there exists a random element in the dynamical behavior of each electron which makes it impossible to predict the specific trajectory to be followed by them, in spite of the precise knowledge of the experimental device, the initial conditions and so on.

The experimental results are equal for low and high electron intensities, with the sole restriction that in this last case the beam intensity must be weak enough to prevent electron-electron interactions. This reproduction of the diffraction pattern tells us that the statistical behavior of the electrons is precisely determined by the experimental arrangement. In other words, the diffraction pattern is a statistical regularity of the electronic motions, although each one of them is subjected to a hazardous and highly irregular movement. It

is seen a dual aspect in this behavior: the individual movement is chaotic but the set of electrons behave in a predictable way. But then one is carried to conclude that the Schrodinger equation describes the statistical behavior of the electrons and not the individual manner each one of them moves.

It is necessary to point out the difference between the classical dynamical equations of particles, which refers to individual entities and they enable us to describe the behavior of each one of them, while the fundamental QM equation, the Schrodinger equation, describes the statistical behavior of an ensemble of electrons. Consequently, it is incapable to study in a detailed way the movement of any electron belonging to the ensemble. So, we may consider that such a description is not complete, in the sense we cannot follow in detail the path of the individual members.

This interpretation is called the statistical interpretation of QM and it is quite different from the more usual and orthodox one. According to the latest, the Schrodinger equation describes the behavior of just one electron (not an ensemble) which has dual wavelike (wave-particle) properties, and has not well defined position nor momentum, so that one is allowed to perform partial (probabilistic) predictions about its movement. It is well known that this viewpoint leads to physical paradoxes and conceptual difficulties.¹⁴⁻²³

Within the realm of the statistical interpretation, one accepts as an empirical fact that each electron possesses an stochastic conduct, i.e. there are (up to now) unknown physical elements which cannot be controlled. From this perspective, the quantum theory reveals itself even more incomplete and of a phenomenological character.

The usual interpretation of QM asserts the completeness of the theory and denies the existence of any reason behind the stochastic behavior of the electron, claiming that:

It is the way of being of it, i.e. the electron in hazardous per se, or, stating that such a class of questions lack of sense, because they imply to consider the particle independently of its observation, etcétera.

The statistical interpretation of QM was proposed long ago by Slater²⁴ and defended by Einstein,¹⁴ Kemble,²⁵ Blochinzew²⁶ and others.

Spectroscopic transitions

In a long article entitled "Physical and Reality"²⁷ Einstein first presented a very illuminating interpretation of QM which may be considered as definitive or his opinion. He analyzed the following problem: a system is initially in its ground state with energy E_1 , the corresponding wave function being ψ_1 . It is then subjected to a small time-dependent perturbation during a finite interval, after which the wave function is,

$$\psi = \sum a_s \psi_s$$

where the a_s are time-dependent function and besides they obey the normalization condition,

$$\sum_s |a_s|^2 = 1$$

But, if ψ describes a real state of the system, then we can ascribe to this state a definite energy E , and in particular, an energy which exceeds E_1 by a small amount (in any case $E_1 < E < E_2$). However, the experiments on electron impact by Franck and Hertz strongly indicate that an individual system can only be one of the discrete energies $E_1, E_2, \dots, E_s$, etcétera. Therefore, Einstein concluded ψ that cannot describe a homogeneous state of the system, but rather it has to represent a statistical description.²²

A careful comparison with Castaño et al's discussion¹ shows the close relationship between. However, Einstein's argument possesses a more general character and this, as well as other well known paradoxes can only be solved²¹⁻²² when one resorts to the statistical interpretation of QM.

DISCUSSION

From a survey of the literature one realizes there are many interpretations of QM^{23,28-32} (and references there in). It is a most remarkable fact, with no parallel in the history of science, that though QM has become the indispensable basic theory for all of microphysics and for much of macrophysics as well, its interpretation has remained a source of conflict from its very beginning in the late twenties until today.³³

Perhaps, the Stochastic description of QM deserves to be mentioned among the various alternative ways of interpretation other than be orthodox one, because up to now it has given consistent and reasonable answers to several quantum riddles.³⁴ The so-called Stochastic Electrodynamics theory has arrived to a consistent picture of quantum processes according to which the stochasticity of the electrons is a direct consequence of the existence of a stochastic background radiation field, and this field, in its turn, is a consequence of the electronic movement. The background field must be identified with the fluctuating vacuum electromagnetic field of contemporary quantum electrodynamics, to fluctuating vacuum electromagnetic field of contemporary quantum electrodynamics, to which this theory attributes a physical status against its usual formal rank. According to this theory, the Schrodinger equation describes the physical system only asymptotically, i.e. it represents an approximate description which holds appropriate once the action of the background field on the particle has yielded a nearly stable situation, or rather, once the system is close to equilibrium. The nature of this paper does not give room to enter into technicalities, so that the interested reader can resort to the pertinent literature.^{2,34-47}

Since up to the present time there is not a totally satisfactory interpretation of QM, we consider really healthy to know the several manners this theory can be brought out. It is especially important form the pedagogical viewpoint, because many questions that students ask cannot be answered in a truly satisfactory way when one restricts oneself with in just one manner if understanding and interpreting the QM.

Many fundamental questions can be raised about the true meaning of QM:

Why Schrodinger equation?

Why we must use operators?

Which is the ultimate physical meaning and origin of the state vectors?

Do Heisenbergs relations refer to our conscience, by reflecting the incertitude of our knowledge, or do they refer to reality, by reflecting a certain intrinsic indeterminism of the electronic motions?

Does QM provide a complete description of reality?

If the description is complete, why we cannot predict, for example, the time disintegration of nucleus, although we may determine it experimentally?

Are we dealing with a complete theory that can furnish only certain experimental results?

If the description is the most complete ever feasible, what is it that limits our capacity to inquire further into the physical world?

If the description is not complete, what does it lack and what else should it contain?

An so on.

So far as one adheres consistently to any well established interpretation some of these questions are meaninagless, while in the view of others a definite answer is essential. But students usually does not belong to any well defined school of thought an they may, and usually do, ask any kind of question. The teacher must be prepared to answer accordingly and reject from the very outset the tempting possibility to solve these conflictive puzzles by arguing that "so is nature", "this question cannot be asked", "it is just possible to explain it in abstract terms", and the like.

In closing, it is our hope that this paper, aimed primarily to answer the question: does QM apply to one or many particles? in a more general sense than Castaño et al's did, should be helpful to

encourage QM and QC teachers to broaden the specific field of interpretations of the quantum theory in such a way that they can have at their disposal the appropriate and convincing answers whenever the inquisitive student expresses his doubts.

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