Do we really need de Broglie's waves?

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Abstract

In this article we refer to what was already stated in [1, pp. 153-156] and, moreover, we propose a particle model that excludes the de Broglie model that associates a wave with each particle. Instead, it we claim that each particle, and in particular the electron, is a corpuscle not perfectly spherical (but which could potentially have a wavy surface), to justify the same results obtained with the classic experiments that are brought to confirm the model of de Broglie. No need, therefore, to refer to the indeterminacy principle and to that of complementarity. What would now be required is the translation this proposal into a solid mathematical model that can make quantitative predictions according to the experimental data, provided that young physicists capable of doing it do not encounter the same ostracism encountered by others for 90 years. Finally, we propose to repeat the experiment of Merli, Missiroli and Pozzi [3] in a fog chamber or similar, to confirm the hypothesis that the single electron follows a very precise trajectory, against the widespread interpretation of Copenhagen.

The validity of de Broglie's wave model of particles has been confirmed both through direct experiments (for example the experiments of Davisson and Germer of 1927 and the more recent ones that have used the electron microscope on diffraction and interference of electrons), as well through numerous indirect confirmations derived from Schrödinger's wave mechanics and quantum mechanics in general. This success has prevented attempts to interpret certain experimental results using different interpretative models[1].

For example, referring to Rutherford's experiment to establish the nuclear model of the atom, we need to consider the impact parameter, according to which the alpha particles undergo deviations of up to 180° (central collision and rebound). This is illustrated in figures 1, where the

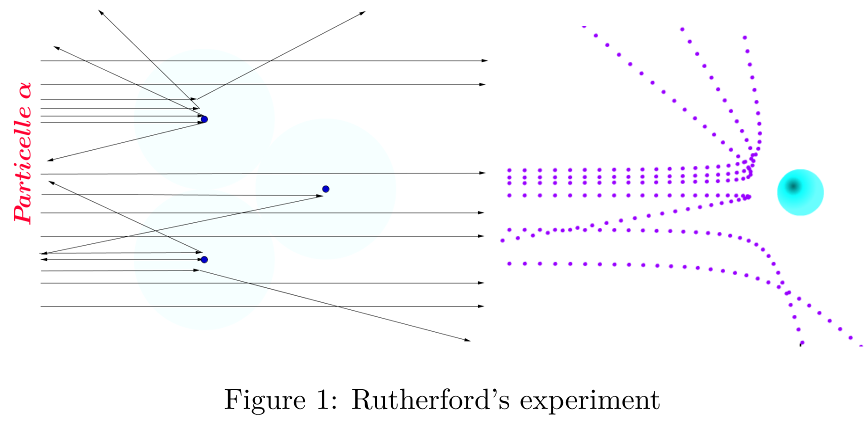

Figure 1: Rutherford's experiment

deflection of the alpha particles is given by the different value of the impact parameter b, whose meaning is specified in figure 2.

[1]In reality, there was the model of the double solution or the pilot-wave (de Broglie 1923-1927, taken up by de Broglie himself and by D. Bohm in 1952), but it was not very successful. On the contrary, this solution was ostracized by the scientific community as reported in [2, pp. 248-9].

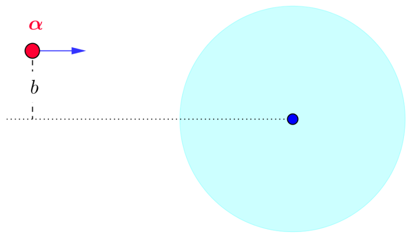

Figure 2: Rutherford's experiment - Impact parameter b

All experiments on the diffraction and interference of electrons refer to a beam of electrons (or even, more recently, to a single electron) hitting a slit or two slits or a lattice of crystals, assuming the beam to be strictly monocinetic (meaning that all electrons travel at the same speed) and well focused! But these circumstances are never achieved in a laboratory. This is due to the mechanism with which the beam is obtained (for example, a termoionic emission from a tungsten filament which emits electrons which are subsequently accelerated and focused with suitable electric and magnetic fields).

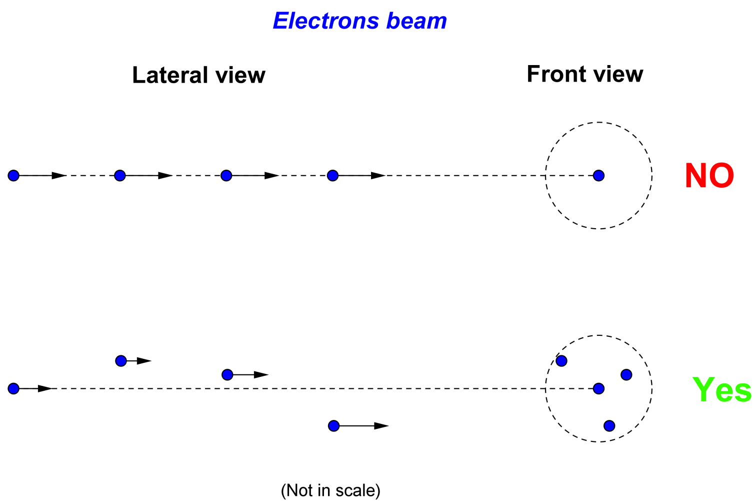

Figure 3: Beam of electrons

Looking at figure 3 we realize immediately that the situation represented at the top (all the electrons perfectly aligned and moving at the same speed) is not obtainable in the laboratory, whereas the one at the bottom is more realistic (where the beam of electrons will have a certain dispersion above and below the imagined theoretical direction)[2].

This means that each electron in the beam can be expeted to have its own impact parameter, different from that of the other electrons. It will be subject to different deviations from the edges of the slit or of the slits dependig on the impact parameter and its speed.

Finally, instead of mantaining, as we do, following de Broglie since 1923, that to an electron or other particle is associated a wave with a wavelength measured as

$$\lambda = \frac{h}{mv}$$

(h Planck constant, m mass of the particle, v velocity of the particle), having never seen these particles directly, could one not suppose that particles, instead of being considered pointlike or perfectly spherical, could have a spherical shape but with a wavy surface, as in Figure 4, where the number and depth of the 'protuberances' are only an example[3].

[2]The same thing could be said of the experiments made with light, considering its corpuscular, photon model.

[3]Obviously anything could affect the perfect spherical symmetry. Meanwhile, a little help in this direction comes from the fact that each electron, for example, has its own intrinsic magnetic moment that could affect experiments like the passage of electrons through two slits. Research is underway to find out whether there is also an electric dipole moment. Individually or combined these intrinsic moments, added to the proposed shape, could interact with the apparatus and provide, statistically, the observed results.

By examining the screen that collects these electrons, one gets the impression that the result is similar to that obtained with the mathematical model of a beam of light waves! In this way a particle continues to be a particle and only the collective behavior of many particles (which have approximately the same speed and slightly different impact parameters) gives the impression of dealing with a particle-wave. In addition, it could be said that if the difference between the impact parameters (and the value of the velocity of the single electrons) contributes to the broad distribution of the traces of the electrons, the fact that the surface of the electrons is undulated could contributes to the formation of the lines on the screen (the particles bounce with their protrusions against the edges of the slits). It does not appear that such a model has ever been subjected to in-depth analysis from a mathematical point of view, even though it may be very difficult to carry out. After all, de Broglie's hypothesis forms the basis of a model that works. But that does not mean that it is the only and the best one! Perhaps some young, willing physicists (one who can survive the censure of all the defenders of the Copenhagen interpretation) could obtain some useful results, bearing in mind what was said here.

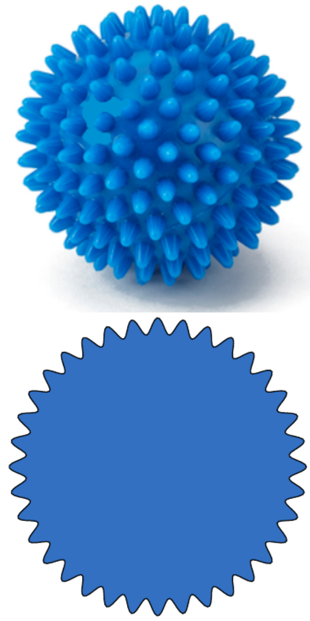

Figure 4: Particle with wavy surface and relative diametral section

In September 2012, the magazine Physics World launched a survey to establish what the most beautiful experiment in Physics is. The winner was an experiment measuring the interference of an electron beam from two slits, with passage, as claimed by the authors, of one electron at a time. This experiment was performed in Milan in 1974 by three young Italian scientists from the University of Bologna: Merli, Missiroli and Pozzi, who obtained an interference pattern left by the electrons on a sensitive plate as shown in Figure 5:

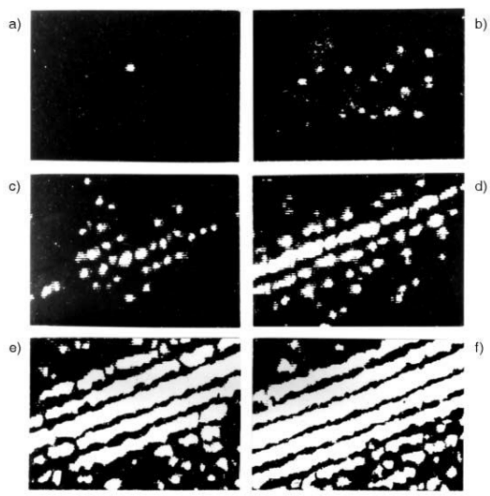

Fig. 2. – Frange di interferenza per valori crescenti della corrente del fascio (da *a*) ad *f*)) e tempo di registrazione costante. Si osservano frange di interferenza anche con tempi molto lunghi di registrazione ed elettrone singolo passante.

Figure 5: Electron Interference: http://l-esperimento-piu-bello-della-fisica.bo.imm.cnr.it/

The authors who obtained the Figure 5 thus commented on their results:

> *We can therefore conclude that the phenomenon of interference is a consequence only of the interaction of the single electron with the experimental apparatus. At this point, to interpret the interference fringes we can think that one or the other of these conditions occurs:*

a) The electron ceases to be a particle and is distributed continuously in space in a similar way to a wave;

b) the electron is a particle that arrives at a well-defined point on the screen by impressing a single grain of the photographic emulsion and the interference figure is the statistical result of a large number of electrons.

...the electrons arrive on the screen as if they were particles, but their probability of arrival is determined by a curve that is known to us in the study of interference phenomena of light, where it represents the distribution of light intensity. It is in this sense that the electrons behave like waves [3, p.94, boldface and translation RS].

The reported citation does *not* exclude the statistical interpretation of the behavior of electron-particles (point b) above), by not taking for granted the interpretation of electrons as waves, interpretation that would seem to prevail from the film made to explain the various phases of the experiment (https://www.youtube.com/watch?v=tMl9Me2hoLE). In fact, at the end of the film, the authors state:

...The behavior of the electron can be represented by a wave .... What we observe is the statistical result of a large number of events . The image that we observe on the screen represents the sum of a large number of independent events each of which represents the interaction of a single electron with the experimental apparatus.

where the first statement (preceded by another in which the electron-wave is said to be a model that can explain the observed final figure) may seem to contrast with the rest of the quotation. This other citation from the article also seems to contrast with that statement:

Interference fringes (and also diffraction fringes) are not therefore due to the fact that the electron is continuously distributed in space and becomes a wave (in fact in in this case we should have had fringes of decreasing intensity as the intensity of the current decreases). The electron manifests itself as a particle whose interaction with the experimental apparatus ... gives rise to a spatial distribution that can be described mathematically by a wave. ...In conclusion, the electrons arrive on the screen as if they were particles, but their probability of arrival is determined by a curve that is known to us by the phenomena of interference of light, where it is the distribution of light intensity. It is in this sense that the electrons behave like waves.[3, p.96]

Hence, a simple analogy.

Looking carefully at the partial figures (from *a* to *f*) of Figure 5, we see clearly, especially in *a* and *b*, that initially we have precise indications on where the electrons have hit, they followed a very precise trajectory. There is no wave associated with the first electrons arriving on the screen. There is no reason to suppose a different behavior for the electrons that hit later. Only in successive phases, as the number of electrons hitting on the screen increases over time, do we begin to glimpse the pattern of a typical interference figure. **But this is due only to the statistical effect of the large number of electrons that hit the screen**, each of which follows a different trajectory as a consequence of the model proposed here in Figures 3 and 4. Therefore, assuming that the figure is the effect of a very large number of electrons hitting the screen (even if they pass through the slits one at a time), the same figure could be obtained by supposing the electrons have the ondulated sferical shape proposed in this article. This shape removes the ambiguity and paradox that the electrons can pass simultaneously from the two slits: the electrons pass from a single slit, even if we can not know from which!

As confirmation of what just been stated, it can be pointed out that, by repeating the same experiment several times in the same place or in different places, the same pattern of interference is always obtained. The same pattern *as a whole*, because, if we enlarge the figure obtained several times, the position of the single electrons that have left the trace is not always the same; which means that it is only a statistical behavior of a large number of electrons. On the other hand, in the experiments of collision between elementary particles, it is possible to see with appropriate techniques (such as a fog chamber) if not the trajectory of the particle(s), the effect of their passage. And from the traces left by the particles we can draw different conclusions on their: nature, type of charge, mass, etc. **So, why not repeat the experiment of Merli, Missiroli and Pozzi in a fog chamber (or scintillation or bubble)? It should be possible (at least at the beginning) to see the traces of the first electrons on the plate! Of course there will be spurious electrons that interact with the medium, but should be possible to take it into account, as in figure 6**[4]. We do not believe that this esperiment would be difficult to carry out. The hardest thing will certainly be to fund it, since research programs are always controlled by the usual fans of the Copenhagen school[5].

So the basic controversy between the different points of view concerning quantum mechanics does not relate to its universally accepted results (even from Einstein who was very critical of the Copenhagen *interpretation*) but to whether these results should apply to a single particle or to a macroscopic set of particles of the same type. As we cannot take an electron with tweezers, place it in a determined point and observe what happens when you invest it with a beam of light, some physicists (contrary to what the Copenhagen school claims), agree with the second hypothesis. In fact, there have been a number of serious and complete studies in recent years that have followed this alternative route, despite relying on the same results as the orthodox interpretation of quantum mechanics, that of Bohr and Heisenberg. In this regard, we would refer to two articles:

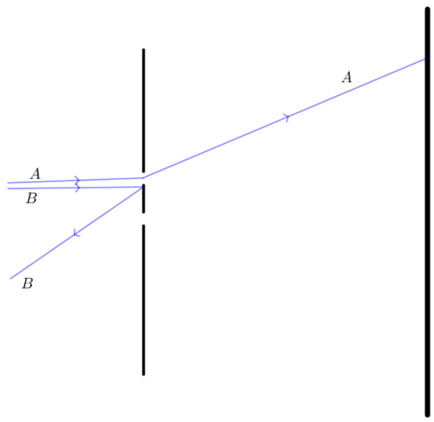

Figure 6: Possible traces of electrons in a fog chamber. Electron A passed by the upper slit. Electron B bounces from the edges. Figure not in scale.

- L.E. Ballentine, *The Statistical Interpretation of Quantum Mechanics, Reviews of Modern Physics*, vol. 42, n. 4, 1970, pp. 358-381 (The same author subsequently wrote a large manual on quantum mechanics, entitled *Quantum Mechanics: A Modern Development*, World Scientific Publishing, 1998, with as guidelines what was written in the article cited).

- U. Klein, *The Statistical Origins of Quantum Mechanics*, *Physics Research International*, vol. 2010, Article ID 808424, 18 pages, 2010.

which themselves refer to vast literature on the matter.

It must be said that de Broglie himself, already in 1927, provided an alternative interpretation of his hypothesis, involving the double solution or the pilot-wave, of which the particle is a singularity. But he soon gave up on defending his youthful idea, conforming to the majority view (that of the Copenhagen school), to return to the pilot-wave only in 1952. The model we propose here (the spherical elementary particle with undulated surface) could bring further support to all statistical interpretations of quantum mechanics, applied not to a single particle, but to an enormous number of particles of the same type.

It is necessary to support this intuitive model with an adequate mathematical model from which we can deduce quantitative results compatible with the experimental data. We hope

[4] Here will it be possible to answer the long-standing question: electron-wave or electron-particle with a trajectory associated with it.

[5] Alternatively we have two options less expensive, just to try: a computer simulation or a mechanical simulation whit thousand of bullets (wave-shaped,a few millimetres in diameter) shooted by a game like rifle against two slits scaled opportunely.

that this model will be able to interpret physical reality better than the quantum mechanics of Heisenberg, Born, Jordan, Pauli, that denies reality itself while relying on mathematical model.

Enrico Fermi wrote the following to his friend Emilio Segré in 1925, after Heinsenberg's matrix mechanics was formulated:

> *My impression is that the progress of recent years has not been very great. ... For my taste,* ***it seems to me that they really start to exaggerate in the tendency to give up on understanding things****.*[6]

And if Fermi said it, they should have started worrying and triggered the reverse gear so as not to give up on understanding. But, sadly, no one heeded Fermi's words.

In effect, demonstrating what stated above remains difficult for the theoretical impossibility of visualizing the elementary particles with direct methods, such as light, as light has a much greater wavelength than the world of atoms, atomic nuclei, electrons and other elementary particles: 10 times larger than the atom, 10^8 (one hundred billion) times larger than the electron. It is like looking at a grain of sand using a tank! So you have to imagine mathematical models and from these, indirectly, with appropriate experiments, try to obtain information on how the microscopic world behaves. But this not mean that the only real thing is the mathematics of the model. We must have the courage to admit that, at this level of reality, only statistical methods are admissible, as was done with the kinetic theory of gases, which allowed us to have correct indications for example on the average speed of a gas molecule, using a thermometer and the mathematics of the gas model. But no one took this to mean that the gas molecules have no physical reality (Well someone did say that a long time ago).

Bohr in 1927 enunciated the *principle of complementarity*: light and particles can have a corpuscular or undulatory behavior; only the specific experiment that we want to perform allows us to choose the most appropriate model; you should not look any further to determine a single behavior!

Heinsenberg, who was a student of Bohr in Copenhagen, formulated the mechanics of matrices in 1925 and the uncertainty principle in 1927; in 1929 he stated that the fifth Solvay congress in Brussels in 1927 had the last word on the interpretation of quantum mechanics, that according to the canons of the Copenhagen school. On the contrary, the French physicist Langevin, speaking of the same congress, affirmed that 'the confusion of ideas reached its maximum'[7].

It must be said that the artificiality and complexity of quantum mechanics has reached incomprehensible levels, completely detached from physical reality and far beyond what Heinsenberg himself could have imagined. It is unthinkable that nature, although written in mathematical code (as Galileo noted), may have reached levels of abstractness such that very often only physicists who have used it or invented it for the first time are the only ones to understand it. And the specialists of a branch of Physics often do not understand the mathematics used and developed for other branches of Physics. For this reason a great gesture of humility is needed, to re-examine the crucial experiments of Physics and try to interpret them with simpler and more intuitive models, where the mathematics used must not mask the simplicity with which the different bricks of physical reality have come together to form the macroscopic world we know.

It is with this spirit that we now propose a simple interpretation of a great crucial experiment of Physics (to be repeated, as written, in a fog chamber or similar and/or to simulate it). Which ought to be accompanied by an appropriate mathematical model (simple!), which can explain the experiment itself, as well as others, starting, for example, from the spectrum of the hydrogen atom. The proposal to most people may appear naive and may put a smile on the lips of many. But the current situation is unsustainable and unrealistic: we must find a road that avoids not only the waves of de Broglie, but also the philosophical blah blah developed around the principle of indeterminacy, the principle of complementarity, the free will (?!?), the end of the principle of causality, and that put an end to the castration of the brains of young physicists operated

[6] [4], p. 209. bold RS.
[7] Circumtance reported in [2].

by Bohr and his school... Specialized magazines, publishers, unmovable professors who occupy the chairs of Physics worldwide continue to ostracise any alternative interpretation to that of the school of Copenhagen. This is a serious problem that must be tackled and overcome, initially by putting forward the proposals considered innovative even on non-specialized sites where there is no censorship, as we do here: we hope that some other young physicist will take up the challenge, spread the research and bring his or her contribution. The important thing is to break the rubber wall that bounces away any alternative idea, irrespective of whether it is a harbinger of positive developments[8].

The news, in September 2011, of the discovery of the famous superluminal neutrinos by the OPERA group at CERN in Geneva was significant: about two hundred renowned scientists and young researchers announced the news with great pomp. At the time, for reasons that are opposed to those of quantum mechanics, almost all of them rushed to corroborate and support the news, with learned interviews in print, television, internet ... The author of this article, against the tide, sent a a letter to three among the major Italian newspapers to argue that the news was a hoax: the letters were not published and the target news organizations preferred to give the floor to the most successful university professors who supported the discovery and *finally decreed the end of the principle of causality also in the theory of relativity* [1, Introduzione].[9]

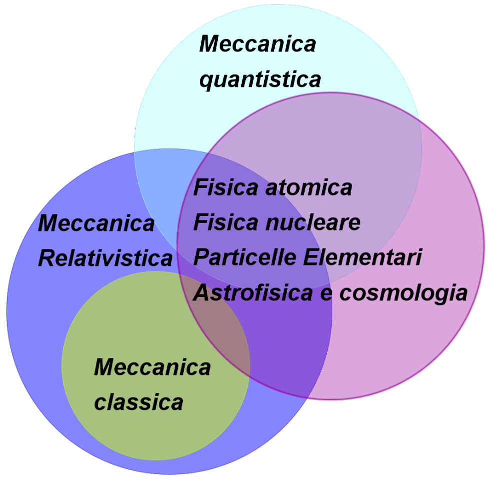

Figure 7: Concatenations between the different chapters of Physics

Other professors and researchers rushed to publish articles full of mathematics (that nobody understood) to validate the discovery and not miss the train to the gold rush. Too bad that the same group of researchers at CERN, a few months later, announced that the discovery was fake because the results they found were not correct (a cable had been screwed in badly!). Of course, the news clouded the view and the brains of many insiders: from a graph such as that in Figure 7 is clear that, should the edifice of the the Relativity collapse, the whole of Physics would collapse!

With quantum mechanics, on the contrary, the principle of infinite precaution has prevailed up to now. It is therefore up to young people to break through the rubber wall, with some encouragement, even financial, for those young physicists who want to beat new paths, even if these may seem uncertain and not very promising. This was also the case for the birth of quantum mechanics, for which it took almost 30 years, from 1900 to 1927, and the work of many physicists such as Planck, Einstein, Bohr, de Broglie, Schrödinger, Born, Heisenberg, Pauli, Jordan, Dirac before it found the form that was imposed in the following years, until today. But it was Dirac himself who, in 1975, wrote:

> *... I think it might very well be that, in the end, Einstein was right, because the current form of mechanics should not be considered definitive. There are great difficulties with*

[8] In the past eighty years, how many research articles, which have had no history or citation, have been published? I do not know if there is a statistic in this regard, but certainly the percentage will be very high. Many researchers who have published these articles have also made a career in universities all over the world.

[9] It must be said that the blog of the particle physicist Marco Delmastro, at the link: http://www.borborigmi.org/2011/09/23/considerazioni-dopo-il-seminario-di-opera-ovvero-di-come-si-misura-la-velocita-dei-neutrini-superluminali-o-meno/ also reporting doubts expressed by someone on the reliability of the measured error, raised issues with the method used in three fundamental points: distance measurement, measurement of travel time, estimate of the error. Some of OPERA's collaborators refused to sign the article. But the gold rush of theorists began all the same as Carlo Cattaneo predicted in his blog of the journal *Le Scienze*: '... does someone want to bet that Monday there will be a flood of theoretical preprint? That it will it go down in history as the international crackpotter day? t To try to make the theory fit a result that is still much discussed?.

current quantum mechanics. It is the best that so far can be done. But we must not believe that this can last forever. ***I think it is very likely that in the future we will be able to obtain an improved quantum mechanics, in which there will be a return to determinism, which, consequently, will justify Einstein's point of view***[10].

Still Dirac, as early as 1930 [5, pp. VII-VIII. Bold RS.], warned against the loss of physical intuition in favor of mathematical formalism:

> *The growth of the use of transformation theory, as applied first to relativity and later to the quantum theory, is the essence of the new method in theoretical physics. Further progress lies in the direction of making our equations invariant under wider and still wider transformations. This state of affairs is very satisfactory from a philosophical point of view, as implying an increasing recognition of the part played by the observer in himself introducing the regularities that appear in his observations, and* ***a lack of arbitrariness in the waysof nature****, but it makes things less easy for the learner of physics.[...] the newer concepts of physics can be mastered only by long familiarity with their properties and uses. [...] the mathematics is only a tool and* ***one should learn to hold the physical ideas in one's mind without reference to the mathematical form****. In this book I have tried to keep the physics to the forefront.*

In 1979, Dirac wrote (from `https://en.wikiquote.org/wiki/Paul_Dirac`):

- **It seems clear that the present quantum mechanics is not in its final form.** Some further changes will be needed, just about as drastic as the changes made in passing from Bohr's orbit theory to quantum mechanics. Some day a new quantum mechanics, a relativistic one, will be discovered, in which we will not have these infinities occurring at all. It might very well be that the new quantum mechanics will have determinism in the way that Einstein wanted.
  - "The Early Years of Relativity" in *Albert Einstein : Historical and Cultural Perspectives : The Centennial Symposium in Jerusalem* (1979) edited by Gerald James Holton and Yehuda Elkana, p. 85

Conclusions

The proposal presented here is deliberately provocative (also because it does not have any quantitative support). I is meant to encourage young people to try new paths and, above all, to look for causal models, or at least to follow statistically causal interpretations of quantum mechanics (as claimed in [1, pp. 178-185]).

Causality must not be abandoned: in any scientific research worthy of this name, it must be the common thread. Otherwise you can leave science to magicians or shamans of any religion. The model of Bohr's hydrogen atom was authentic magician's coup: inspired by the empirical formula of Balmer and the existence of Planck's constant, the contradictory hypotheses[11] of Bohr (1913) were derived entirely on thin air (the rabbit from the magician's hat) and only with the waves of de Broglie (1923-24) they found a semblance of theoretical justification. Then came the Bohr School in Copenhagen, where the brainwashing of young students began, as stated by the Nobel Prize for Physics (1969) Murray Gell-Mann, and from then '*bonjour les dégâts*'!

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[10] P.A.M. Dirac, *Directions in Physics*, H. Hora and J.R. Shepanski, ed., Wiley, Sidney, 1976, p. 10. Quoted in Franch by Franco Selleri, *Le grand débat de la théorie quantique*, Flammarion, 1994, p. 256. Bold RS.

[11] Classical electromagnetism is used to determine the "allowed" orbits of the electron, but at the same time it does not hold good because the electron on the orbits allowed, while accelerating, does not radiate electromagnetic energy and does not collapse.

Physics should do without the so-called 'dualisms' (which are good, perhaps, only in philosophy). We should avoid not only the waves associated with the particles (de Broglie), but also the particles associated with the waves (Planck, Einstein). So a healthy re-foundation should start from a very careful reconsideration of the founding experiments: black body, photoelectric effect, Compton effect ..., avoid the so-called *flea Physics* (quantum jumps), do not confuse the *collective* behavior of a set of equal particles with that of a *single* particle!

Figure 8: Reproduction of a drawing by a former student of RS, done at the end of the author's lesson on Bohr's atom in 1995. The original design is by Aldo Torre. The review is of another former student, Federico Milella, now a professional designer in Luxembourg. On the magician's arm is written: 'Bohr'; on the rabbit's hat is written '$mvr = n\hbar$'.

Grazie Silvia!
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