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Revisions of the Foundations of Quantum Mechanics Suggested by Properties of Random Walk

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Abstract

A new theorem on random walks suggest some possible revisions of the foundations of Quantum Mechanics. This is presented below in the simplified framework of the description of the evolution of a material point in space. Grossly speaking, it is shown that the probabilities generated by normalizing the square modulus of a sum of probability amplitudes, in the setup of Quantum Mechanics, becomes asymptotically close (under the appropriate limiting conditions) to the probabilities generated by the usual causal processes of Classical Mechanics. This limiting coincidence has a series of interesting potential applications. In particular it allows us to reintroduce the concept of causality within the core of Quantum Mechanics. Moreover, it suggests, among other consequences, that gravitational interaction may not even exist. Even though the interpretations of Quantum Mechanics which follow from this mathematical result may seem to bring some unexpected innovations in the context of theoretical physics, there is an obvious necessity to study its theoretical impact on Quantum Mechanics. The first steps toward this aim are taken in the present article.

Keywords: Determinism, Prequantic Physics, Random Walks, Entanglement

1. Introduction

An unexpected property of random walks [1] suggests a possible revision of the foundations of Quantum Mechanics. In the present article, we present first an application of this recently obtained result, and then discuss its potential implications to Quantum Mechanics and Gravitation theory.

In theoretical physics, one usually assumes that the description of a physical system is *complete*, with uncertainty modeled through probabilistic structures. This basic assumption entails, as an implicit consequence, the rejection of the general principle of causality, which relies, basically, upon determinism.

The latter notion is replaced by the evaluation of probabilities, for the various outcomes of the phenomenon in study.

As we shall see, the aforementioned theorem of [1] leads to a different interpretation of probability. Grossly speaking, in this new setup, the notion of randomness reduces to the construction of a simplified model, aiming to cope with disorder in the same way as is usually done in usual thermodynamics. Following the implications of this interpretation, we are led to the surprising conclusion that gravitational interaction may not exist. This comes in agreement with an extraordinary proposal of Poincaré [2], made about a 100 years ago, hinting that the spread of gravitational influence could be null, or worse, negative! This idea was developed by Poincaré to give some simple interpretations of the principle of relativity. (see, Charreton, [3], chapter 3 for details)

It turns out that the modifications of the foundations of Quantum Mechanics which follow logically from [1] do not question in any way its global effectiveness. Quantum Mechanics is well-known to provide an *efficient* model, in the sense that the remarkable agreement of its predictions with observations has not been seriously challenged yet. This is not at all contradicted by our approach. The reason of the coherence between our suggested modified version of the foundations of Quantum Mechanics and the classical one becomes very clear in the simplified setup of [1]. This is due to the fact that, when the observation times become sufficiently large, the probability distributions evaluated under both formalisms become arbitrarily close to each other. In this way, the probability laws arising from the usual Quantum Mechanics become undistinguishable from that following from our interpretation, and which arise from causal processes in the framework of the Classical Mechanics of Lagrange, Hamilton and Jacobi. The possible physical differences between each of the two models should therefore only be detectable on observations made on an extremely short time scale.

The conclusion of the present article will show that Quantum Mechanics can be interpreted in terms of Statistical Mechanics, the inner mechanisms of which being left to some form of Maxwell demon.

2. Interpreting the Motion of a Material Point through Random Walks

2.1. Classical Mechanics

We start by a physical analysis of the motion of a material point A in the framework of *Classical Mechanics*. We limit ourselves to the most simplified model of *random walk*, where A is restricted to move on a linear univariate lattice without friction. Given a time origin t_0 and a time unit ε, we assume that A receives a sequence of *shocks* from an exterior generic source denoted by B, at times $t_j = t_0 + j.\varepsilon$, for $j = 0, 1, \cdots$. The shock at time t_j may be *backward* or *forward*, which is denoted, respectively, by $F_j = 1$ or $F_j = -1$ for $j = 0, 1, \cdots$, where $\{F_j : j \geq 0\}$ is a sequence of *outcomes* whose properties be made precise later on. We denote the *energy* of A at time t_j by E_j. We let E_0 be arbitrary and assume that, for $j = 0, 1, \cdots$, the energy E_j of A is modified, immediately after t_j by adding or subtracting a fixed quantum $w > 0$ of energy, depending on the sign of F_j. Thus, for any time $t \in (t_{j-1}, t_j]$, $j \geq 1$, the *energy* of A is defined by $E_j = E_0 + k_j.w$, where we set $k_j = F_0 +, \cdots, + F_{j-1} \in \{-j, \cdots, j\}$. For each $N \geq 1$, on the time-period $[t_0, t_N]$ the *trajectory* of the material point A is defined by $\{(t_j, E_j): j = 0, \cdots, N\}$, and characterized by E_0 and either of the sequences $\{E_j: j = 1, \cdots, N\}$ or $\{F_j: j = 0, \cdots, N-1\}$.

The following notation will be useful. As usual, we will let $\mathbf{N} = \{0, 1, \cdots\}$, (resp. $\mathbf{N}^* = \{1, 2, \cdots\}$), denote the set of nonnegative (resp. positive) integers, and $\mathbf{Z} = \{0, +1, -1, \cdots\}$ denote the set of signed integers. Moreover, we will let $\mathbf{R}$ (resp. $\mathbf{C}$) denote the set of real (resp. complex) numbers, and set $\mathbf{Q}$ for the set of rational numbers.

For each $N \in \mathbf{N}$, we set $\mathbf{J}_N = \{-N, -N + 2, \cdots, N - 2, N\}$, and for each $j \in \mathbf{N}^*$ and $k \in \mathbf{Z}$, we denote by $n(j, k)$ the number of trajectories of $\{(t_i, E_i): i = 0, \cdots, j\}$ which, at time t_j, end up with energy equal to $E_j = E_0 + k.w$. For convenience, we extend the definition of $n(j, k)$ to $j = 0$, by setting $n(0, 0) = 1$ and $n(0, k) = 0$ for $k \in \mathbf{Z} - \{0\}$. A simple combinatorial analysis shows that, for all $j \in \mathbf{N}$ and $k \in \mathbf{Z}$, these quantities fulfill the equalities $n(j, k) = n(j, -k)$, and are given by

$$n(j,k) = \binom{j}{(j+k)/2} = \frac{j!}{\left(\frac{j-k}{2}\right)!\left(\frac{j+k}{2}\right)} \quad \text{for} \quad k \in \mathbf{J}_j$$

$$n(j,k) = 0 \quad \text{for} \quad k \notin \mathbf{J}_j,\ k \in \mathbf{Z};$$

In what follows, we are concerned with the trajectories of A, in the time interval $[t_0, t_L]$, and limit ourselves to the case where L in $2\cdot\mathbf{N}^*$ is even and positive. The treatment of the case where L in $2\cdot\mathbf{N} + 1$ is odd is similar and omitted. There are 2^L possible trajectories depending upon the values of $\{F_0, \cdots, F_{L-1}\} \in \{-1, 1\}^L$. The proportion of trajectories ending with energy level equal to $E_L = E_0 + k\cdot w$ at time t_L is denoted by $p(L, k) = 2^{-L}\cdot n(L, k)$.

We observe that $p(L, k) = 0$ unless $k \in \mathrm{J}_L$, which, in view of $L \in 2\cdot\mathbf{N}$, implies that $k \in 2\cdot\mathbf{N}$ is even. We endow this *random walk* on $[t_0, t_L]$, with a probability structure (Ω, A, P) giving equal probability to each of the 2^L distinct trajectories ending at time t_L. The latter correspond to the 2^L possible outcomes of $\{F_0, \cdots, F_{L-1}\}$ which are given equal probability. In this setup, the probability of a *forward* shock of A by B is identical to that of a *backward* shock.

In words, $p(L, k) = \mathrm{P}(E_L = k.w + E_0)$ defines, over $k \in 2\cdot\mathbf{Z}$, the probability that the particle A reaches the energy level $k.w + E_0$ immediately after the time t_{L-1}, *id est* after L shocks. It will be convenient to denote by X_L a random variable on (Ω, A, P) fulfilling $\mathrm{P}(X_L = k\cdot w + E_0) = p(L, k)$ for $k \in 2\cdot\mathbf{Z}$.

As given above, the trajectory $\{(t_j, E_j): 0 \leq j \leq L\}$ may be qualified as *natural*, with the meaning that it fulfills the principles of Classical Mechanics. Under the usual assumptions of this theory, the energy and speed of the material point A, may be assumed to remain constant between each of the successive shocks. In addition, the *action integral* of A in the time-period (t_0, t_j) is of the form $S = n.w.\varepsilon$ for some appropriate integer $n \in \mathbf{Z}$.

Up to now, we have only considered the variations of the energy of A through time. We let m_A denote the *mass* of A, and set $q(t_j)$ (resp. v_j) for the position (resp. speed) of A at time t_j, for $j = 0, 1, \cdots$. Obviously, when $v_0 > 0$ is large,

$$\frac{1}{2} m_A \left(v_{j+1}^2 - v_j^2\right) = \left(1 + o(1)\right) v_0 m_A \left(v_{j+1} - v_j\right) = wF_j,$$

so that

$$q(t_L) - q(t_0) = v_0 \varepsilon L + \left(1 + o(1)\right) \frac{w}{m_A v_0} \sum_{j=0}^{L-1} F_j \left(t_L - t_j\right).$$

Denote by $\mathbf{E}$ the expectation with respect to (Ω, A, P). Obviously, $\mathbf{E}(F_j | E_L - E_0 = k.w) = k/L$ for k in $\mathbf{J}_L$, so that, if we denote by $Q(L, k) = \mathbf{E}(\mathrm{q}(t_L) | E_L - E_0 = k.w)$ the mean value (or expectation) of the (random) position of A at time t_L, given that $E_L - E_0 = k\cdot w$, we obtain the approximation, for $k \in J_L$ and all large v_0,

$$Q(L,k) = q(t_0) + v_0\varepsilon L + (1+o(1))\frac{kw\varepsilon(L+1)}{2m_A v_0}.$$

The latter formula makes use of the observation that

$$\sum_{j=0}^{L-1}(t_L - t_j) = \frac{1}{2}\varepsilon L(L+1).$$

The above approximation holds under the general assumption that the energy brought to A, within the time-period $[t_0, t_L]$, and by cumulation of the individual shocks with B, is small with respect to the initial energy of A at time t_0. The latter added energy is proportional to

$$\max 0 \le j \le L\left|F_0 + \cdots + F_{j-1}\right| = (1+O\mathbf{p}(1))\sqrt{L}.$$

We may therefore reduce our assumption to

$$L^{1/2}\left\{\frac{w}{m_A v_0^2}\right\} = o(1)$$

The above approximation has an interesting consequence. Since $Q(L, k)$, as given above, is a linear function of the energy $E_L = E_0 + k\cdot w$ at time t_L, we see that, subject to a proper choice of the scale coefficients, we may (approximately) identify $Q(L, k)$ with k.

By all this, we observe that the explicit choices of the time-scale e and of the energy quantum $w > 0$ associated with each individual shock, are important factors in the description of the *natural* trajectory of A. We will not discuss here the physical problem of fitting the corresponding constants on experimental data sets. We limit ourselves to some specification of the range of values which correspond to the phenomenon we have in mind. Typical examples would lead us to choose w of the order of 10^{-20} Joules, with m_A being of the order of the mass of a neutron (or of that of a hydrogen atom). As for ε, one would choose a value of the order of $\varepsilon = \varepsilon(A) = 10^{-12}$ Seconds. This should correspond to the setup of an *individual material point*, denoted by $A = A_1$.

A more general setup would be to assume that $A = A_M$ is composed by a cluster of a number $M \ge 1$ (possibly different) individual material points. We would then assume that the mass of A_M should be of the order of $M\cdot m_{A1}$, with $\varepsilon = \varepsilon(A_M) = \varepsilon(A_1)/M$.

This concludes our simplified description of the trajectory of A in the setup of *Classical Mechanics*. We note for further use that, in this framework, the trajectory of A on (t_0, t_L) is completely determined by its initial conditions at time t_0, and the (unknown) random sequence $\{F_j: 0 \le j \le L - 1\}$. The best information which is available here, concerning the position of A at t_L, reduces to the knowledge of the probability law $P(E_L - E_0 = k\cdot w) = p(L, k)$ for $k \in \mathbf{Z}$.

2.2. Quantum Mechanics

In contrast to the previous description of the trajectory of A, under the assumptions of Classical Mechanics, we proceed below to a parallel analysis, but in the framework of *Quantum Mechanics*. In this setup, B is ignored, and we may assume (even though this is a rather theoretical point of view) that A is *isolated*. The physicist ignores the B particles but he has at his disposal the quantum of action discovered by Planck, the non commutative relationships among operators, the Schrödinger equation, the Feynman postulates, *i.e.* a universal constant h and several roughly equivalent different approaches. In what follows, it will be convenient to proceed under the general formalism of Feynman.

We first modify, to some extent, the range of variation of A. In the first place, we proceed in continuous energy $E(t)$, instead of limiting, as was previously the case, the values of $E(t)$ in the set $\{E_0 + j\cdot w: j \in \mathbf{Z}\}$. We therefore consider a trajectory, as defined in Classical Mechanics, of A with continuous $E(t)$ energy, E and $t \in \mathbf{R}$, and more specifically for $t \in (t_0, \tau)$, where $\tau \in \mathbf{R}$ fulfills $t_0 < \tau \le t_{2.L} = t_0 + 2\cdot L\cdot\varepsilon$. Here, as above, $L \in 2\cdot\mathbf{N}^*$ is an even integer. We do not necessarily assume here that t_0 and $t_{2.L}$ are finite, and our description will remain valid when $t_0 = a - L\cdot\varepsilon$, $t_{2\cdot L} = a + L.\varepsilon$, $t_L = a$, $a \in \mathbf{R}$, by letting the endpoints t_0 and $t_{2.L}$ converge, respectively, to $-\infty$ and $+\infty$.

The trajectory of A is given by$\{(t, E(t)): t_0 \le t \le \tau\}$, where $E(t)$ denotes the energy of A at time t. This trajectory is *admissible* if the corresponding *action integral* $\{S(E(t)): t_0 \le t \le \tau\}$, along this trajectory, is properly defined. We define the *probability amplitude* at time t, by the quantity

$$a(E(t)) = \exp\left\{\frac{2i\pi S(E(t))}{h}\right\} \in \mathbf{C}$$

We next fix an energy quantum $w \in \mathbf{Q}$ and an even integer $k \in 2.\mathbf{Z}$, and consider the *admissible* trajectories $\{(t, E(t)): t_0 \le t \le \tau\}$, *physically possible* fulfilling. $\tau \in \mathbf{Q}$, $E(\tau) - E(t_0) \in \mathbf{Q}$, and $k\cdot w\text{-}w \le E(t) - E(t_0) \le k\cdot w + w$.

Let us assume, to proceed under Feynman's formalism, that these trajectories compose a set $\mathbf{T}(L, k)$ with cardinality $M(L, k)$. If $1 \le m \le M(L, k)$ denotes the index of a trajectory in $\mathbf{T}(L, k)$, we denote by $a_m = a(E(t))$ the corresponding probability amplitude.

Set now $\psi(L,k) = \sum_{m\in M(L,k)} a_m$.

Under Feynman's approach, $\psi(L, k)$, is a sum of *probability amplitudes*, which characterizes the state of the isolated particle A. The square modulus of $\psi \in \mathbf{C}$, namely $|\psi|^2 = \psi^* \cdot \psi$, is given the interpretation of an un-normalized probability distribution.

At this point, we note that the cardinality $M(L, k)$ of $\mathbf{T}(L, k)$ is unknown and we should point out that $\psi(L, k)$ is usually interpreted as some kind of limit multiple integral, usually known under the name of *path integral*, and whose mathematical theory is not yet achieved in a coherent way.

To evaluate the path integral $\psi(L, k)$, it is natural to limit the summation in its definition to a selection of distinct trajectories, subject to be bounded away from each other, above some selected threshold z, and along N regularly spaced times within $[t_0, \tau]$. In a second step we evaluate $\psi(L, k)$ as the limit of the so-obtained summation as N increases towards ∞ and z decreases towards 0.

We now apply this method, with the choice of times $\{t_j: 0 \le j \le 2.L\}$, which t_j has been defined in the previous subsection, and evaluate the corresponding approximations of path integrals on $(0, \tau)$, for $\tau = t_j$, and $j = 1, \cdots, 2.L$.

The enumeration of the different paths is then quite simple, since the indexation with respect to m is obvious, and because of the fact that we may set $a_m = 1$ for the probability amplitudes pertaining to m. This simplification is rendered possible by choosing w and ε in such a way that $w \cdot \varepsilon = K.h$, where $K \in \mathbf{N}^*$ is an integer which may depend upon A. We so obtain that $S(E(t))_m = n \cdot w \cdot \varepsilon = n \cdot K \cdot h$, $n \cdot K \in \mathbf{Z}$, which, in turn, implies that

$$a_m = \exp\left\{2i\pi S\left(E\left(t\right)\right)_{m/h}\right\} = 1.$$

Since $a_m = 1$, the summation of probability amplitudes with respect to m reduces to counting, for any value of $j \in \mathbf{N}$ with $0 \le j \le 2 \cdot L$, the number of paths of the random walk ending up at time t_j with energy equal to $E_j = k \cdot w + E_0$. As follows from the results of the previous subsection, the number of *natural* trajectories of A in the time-period (t_0, t_j), subject to the condition $E_j = k \cdot w + E_0$, is equal to $n(j, k)$. It follows that

$$\psi\left(L,k\right) = \sum_{j \in \mathbf{N}, j \le 2L} n\left(j,k\right) \quad \text{for} \quad k \in 2\mathbf{Z}.$$

The corresponding probability distribution, obtained by normalizing the square modulus of the sum of the probability amplitudes is therefore given by

$$p'\left(L,k\right) = \frac{\left|\psi\left(L,k\right)\right|^2}{\sum_{\ell \in 2 \cdot \mathbf{Z}}\left|\psi\left(L,\ell\right)\right|^2} \quad \text{for} \quad k \in 2\mathbf{Z}.$$

Note: We stress the fact that, as given above, the definition of $\psi(L, k)$ coincides *exactly* with that following from the approach of Feynman. The only approximation we have made consists to restrict the summation of probability amplitudes to the *natural trajectories*, in the sense given in the previous subsection. All the theoretical problems pertaining to the convergence of the summations defining $p'(L, k)$ disappear after this simplification.

This concludes our simplified description of the trajectory of A in the setup of *Quantum Mechanics*. Under this approach, the concept of trajectory is replaced by a definition of states entirely defined in terms of the complex-valued path integrals $\psi(L, k)$, and the probabilistic structure is defined in terms of a probability space (Ω', A', P') which is distinct from the probability space (Ω, A, P) of Classical Mechanics. On this new probability space, $p'(L, k)$ is given the interpretation of the probability $P'(X'_L = k) = p'(L, k)$, where X'_L is a random variable characterizing the situation of A at time t_L.

2.3. Quantum Mechanics versus Classical Mechanics

We now compare the results following from the theories given in each of the previous two subsections, namely that of Classical Mechanics and of Quantum Mechanics. We proceed knowing h, $w = K \cdot h/\varepsilon$ and ε but with $\{F_j: j = 0, \cdots, L\}$ unknown. Towards this aim, the main result (and its potential generalizations) of [1] will be instrumental. We inherit the notation of the above subsections.

In the setup of *Classical Mechanics*, we keep in mind that $Q(L, k)$ denotes the mean position (with respect to the probability $P(\cdot)$ of A under the energy condition $E_L = k \cdot w + E_0$. We recall from the previous sections that, subject to appropriate choices of origin and scale, we may approximate $Q(L, k)$ by k. Therefore, $p(L, k)$ remains (up to this approximation), very close to the P-probability that the position of the material point A is equal to k.

As for *Quantum Mechanics*, the situation is more than slightly different. It will be useful to recall some historical facts related to this theory. Shortly after the discovery of the fundamental equation of quantum mechanics by Schrödinger, Born proposed to interpret the squared modulus of the complex amplitudes ψ introduced by Schrödinger as an un-normalized density of the *probability of presence* of the particle at the space-time point (q, t) in consideration. This interpretation of Born, strongly supported by Bohr, is presently known today as the *Copenhagen Interpretation* (or *Measure Postulate*) of Quantum Physics.

According to the Copenhagen Interpretation, the probability distribution $\{p'(L, k): k \in 2 \cdot \mathbf{Z}\}$, defines (with appropriate choices of scales and units) the P'-probability that the material point A is located at a position k (or, more precisely, in the interval $(k - 1, k + 1)$ at time t_L (or, more precisely, in the interval $(t_0, t_{2 \cdot L})$. The above description of the random walk in terms of quantum mechanics can also give to $p'(L, k)$ the meaning of the P'-probability that the material point A has, an energy level equal to $k \cdot w$ (or, more precisely, an energy taking values in the interval $((k-1) \cdot w, (k+1) \cdot w)$ at time t_L (or, more precisely, in the interval $(t_0, t_{2 \cdot L})$.

The expressions of the probability distributions $\{p(L, k): k \in \mathbf{Z}\}$ and $\{p'(L, k): k \in \mathbf{Z}\}$ differ to some extent. Letting X_L (resp. X'_L) denote a random variable on (Ω, A, P) (resp. $(\Omega', A', \mathrm{P}')$) with distribution given by $p(L, \cdot)$ (resp. $p'(L, \cdot)$), the meaning of the main result of [1] is that, as L tends towards ∞, $\mathrm{L}^{-1/2} \cdot X_L$ and $\mathrm{L}^{-1/2} \cdot X'_L$ have the same limiting distribution, namely the standard normal N(0, 1) law.

The convergence in distribution, as L tends towards ∞, of the random variable $L^{-1/2} \cdot X'_L$ towards the N(0,1) standard normal law follows from [1], whereas the convergence in distribution to N(0,1) of $L^{-1/2} \cdot X_L$ is a straightforward consequence of the well-known properties of the binomial distribution.

At this stage, the similarities of the asymptotic distributions of $L^{-1/2} \cdot X'_L$ and $L^{-1/2} \cdot X_L$ is the best explanation we can offer for the physical interpretation, in Quantum Mechanics, of the probability distribution generated by sums of complex amplitudes.

Note: The useful trick of selecting $K \in \mathbf{N}^*$ such that, for the material point A, we get $a_m = 1$, requires $w \cdot \varepsilon$ to be a multiple of h. This choice is not possible when $w \cdot \varepsilon$ does not fulfill this condition, and in particular, when $w \cdot \varepsilon = f \cdot h$, with $f < 1$. We mention that an adaptation of our arguments allows to extend our results the case where $f \in \mathbf{Q}$ is rational (allowing, in particular, the case where $f < 1$. We omit the details of this extension.

Note: The theorem in [1], allowing the approximation of $\{p(L, k): k \in \mathbf{Z}\}$ by $p'(L, k): k \in \mathrm{Z}\}$ for large values of L, can be extended to the case where the square modulus, $|\psi(L, k)|^2$, is replaced by a more general convex function of $|\psi(L, k)|$, such as $|\psi(L, k)|^r$ for some $r \geq 1$. This has a physical interpretation in terms of the state of the particle in study.

3. Possible Revisions of the Foundations of Quantum Mechanics

3.1. Introduction

The preceding arguments lead us to the following speculative suggestions, which are likely to compose the first steps towards a coherent proposal to revise the foundations of Quantum Mechanics.

We consider a material point A defined, initially, only under the sole assumptions of *Quantum Mechanics*. Our general idea is to give a physical meaning to the trajectory of A, simultaneously, and under the assumptions of *Classical Mechanics*. This is rendered possible by a *coupling* argument, which turns out to be an established mathematical tool, see, e.g., [4], which allows us to embed the probability spaces (Ω, A, P) and $(\Omega', A', \mathrm{P}')$ into a single joint space. The consequence of this construction is as follows. On an appropriately enlarged mathematical space, we may define a copy of the physical definition of the material point A under the assumptions of *Quantum Mechanics,* and consider that the same point has, in the same time, a trajectory defined under the assumptions of *Classical Mechanics*, but with a different probability law. Since, under the assumptions of Classical Mechanics, the motion of A in space (as defined above) requires the action of some exterior particles, previously denoted under the generic notation B, we must give life to these particles which have, in this setup, only a virtual (mathematical) existence. At this point, we will not distinguish the notion of *physical existence* from that of *mathematical existence*, for these particles, which are only present through their effects on A within the probabilistic structure (Ω, A, P). To simplify our exposition we give to these virtual particles the qualification of *alien* [in French, *ultramondaine*], stressing the fact that they live in an *exterior* (mathematical) *world*.

A second step in this construction will come from the observation that, to render the system physically coherent, we must define at least two states for each isolated particle, depending upon whether they are *stable* or *unstable*. The existence of these states underlies the possibility of a particle to interact with the outside world, and, in particular, to be detected or not.

As we shall see, the consequences of the above mathematical construction are anything but virtual. They bring some important innovations to a consequent part of theoretical physics. In particular, they allow some new interpretations of causality, and renew the physical notion of trajectory. Pushing further our analysis, we are even led to question the existence of gravitational interaction.

3.2. A speculative Proposal to Revise the Foundations of Quantum Mechanics

As mentioned above, our construction relies on the mathematical introduction of a large set of *alien* (or *ultramondaine*) particles. Let us treat these *virtual* particles as if they were *physically existent*, and discuss the corresponding consequences. In some way, this is not totally irrealistic, since these alien particles are physically present through more or the less observable effects. The alien particles should compose some kind of universal cloud, and we can think of these objects as being small or almost punctual (with respect to the usual physical scale of elementary particles), moving around with a speed close to that of light, with unknown mass (which we can also figure out as small), and with unknown energy. The role of these alien particles should be to move around in space, interacting with other (non-alien) particles in the subatomic scale, through a series of random *shocks* (this being a generic term to denote an interaction resulting in some transfer of energy from one particle to the other), forcing the latter particles into Brownian-type trajectories.

We can show that such *shocks* allow to introduce quanta, without the need of the preliminary introduction of non commutative relationships among operators. Details about this will be given elsewhere. To give some physical meaning to shocks of a basic (non-alien) particle with an alien particle, we need postulate either the existence of an unstable state of the basic particle, following a shock and having a small persistence, or, following each schock, some effect on the inertial mass of the basic particle. The existence of distincts succesives states leaves room for interactions of the basic particle with the exterior, which, in particular, should allow for their detection.

Note: A detecting device located in the neighborhood of a basic particle would be sensitive to its presence only through its mean energy. It would therefore give right or wrong answers depending upon the circumstances. This property underlies, in some way, all possible types of interference phenomenon.

Three major innovations brought by Quantum Mechanics, and by essence non-existent in the range of Classical Mechanics, are *Planck's constant*, the notion of *spin* for a particle and the notion of intrication (or entanglement) *via* quantum correlations. We make a side-note that the notion of *spin of a particle* is improper, in the sense that spin is not a character of the particle by itself, but of the particle in its environment, and over a finite time-period.

To complete our description, we need to provide a realistic commutative geometric model of quantum physical phenomenon coping with mutual shocks of basic particles (aside of that due to the alien particles), and explaining for the state changes of particles.

A very natural objection to our physical introduction of alien particles is as follows. Whereas Quantum Mechanics succeeds very well in modeling almost perfectly a number of physical phenomenon, with the only aid of Planck's action constant h, our approach, at first glance, does not give any precise information on the quantitative influence of shocks of alien particles on the behavior of basic particles. There must be some link between the density of such alien particles in a space volume and Planck's constant, in terms of a Poisson-type law, but the appropriate model is not exposed here.

On the other hand, the amazing skill of Quantum Mechanics to model successfully various complex phenomenon does not exclude the possibility that it could be interpreted through statistical mechanics. If such is the case, then this interpretation should rely on mathematical models allowing some *hidden variables* influencing the particles in study. This idea motivates our approach, together with the following proposal, which we give as a general interpretation of our construction.

The physical phenomenon, modeled perfectly or imperfectly, by Quantum Mechanics, can be considered as limit forms of similar models based upon statistical versions of Classical Mechanics. As a consequence, the specific concepts of Quantum Mechanics, such as the spin, Plank's constant, and intrication, should have existing interpretations in the framework of Classical Mechanics. In addition, the afore-mentioned interpretations are likely to provide some more precise descriptions within short time scales than that given by Quantum Mechanics.

In physical applications, most of the times, practical considerations dominate the theoretical viewpoint. As an example of this, we recall that the pressure of a gas in a closed volume is well interpreted, via the molecular statistics of gases. On the other hand, Mariotte's law, which has largely anticipated the development of this molecular theory, is already quite accurate, and with a precision largely sufficient for most applications. Quantum Mechanics appears to be some kind of Mariotte law, very much adapted to applications, and very useful as a consequence of its verified adequation with observations. The fact that this Mariotte law should be deducted from statistics derived from Classical Mechanics does not change much, except if some differences can be detected between both theories. We conjecture that the latter are likely to be detected in the future. Since our discussion shows that they can only exist on very short time scales, we are led to think that one should detect such differences, for example, in the setup of quantum computers.

The bases of quantum computers and more generaly the bases of quantum mechanics are exposed today in an *orthodoxal* form by Serge Haroche [5].

4. A Two-Fold Conclusion

4.1. Basic Proposals for Present

The concept of trajectory, fundamental in Classical Mechanics, and basically excluded in Quantum Mechanics, is reintroduced through our proposal of building a combination of both approaches, via the introduction of *alien particles*, and multiple states for basic particles. In so doing, we reject non-commutative relations between operators, at the price of considering stable and unstable states for basic particles such as the photon, electron, neutron, or others. This last introduction appears as essential for the construction of a commutative geometry of particles, allowing in particular to restore the principle of causality.

A commutative geometric model has the advantage of setting aside most of the usual "mysteries" of Quantum Physics. In particular:

1) The so-called *tunnel effects* corresponding to potential level up-crossings receive a natural explanation for apparently isolated systems, if one considers the pervasive influence of *alien particles*;

2) The natural disintegration of particles, such as that of the neutron, when it occurs, is interpreted not by some kind of natural magic, but rather, through the occurrence of appropriate shocks due to *alien particles*;

3) The undulatory character of a particle, as well as interferences of a particle with itself can be interpreted by changes of the particle state generated by a shock with an *alien particle*;

4) By this approach, the spin appears not to be a character of the particle, but rather, a character of the trajectory of the particle during some appropriate time length. It follows that the conclusions which may be drawn from the experiments aiming to cope with Bell's inequality can be reinterpreted anew;

5) Since quantum *space* is not any more considered as empty, but rather occupied by the *alien particles*, the so-called *ultraviolet catastrophe*, can be better understood. Moreover, the possibility of building a link between the cosmological constant and the energy of *empty space* appears as more natural.

We note that the discussion on what should be the proper interpretations of Quantum Mechanics has given rise to a number of controversies, opposing the greatest names of physics during the last 80 years. The debate is far from being closed at present, and we would like to mention the following comments of Franco Selleri [6], which support, to some extent, our point of view.

One among the following three statements must be in error:

1) *Nuclear objects exist independently of the human observers.*

2) *Any kind of interaction between two objects must tend to 0 when the mutual distance of these two objects tends to infinity.*

3) *Quantum Mechanics is exact.*

The P and P' probabilities, $\{p(L, k): k \in \mathbf{Z}\}$ and $\{p'(L, k): k \in \mathbf{Z}\}$, pertaining to the above-given descriptions of the behavior of A, become asymptotically close to each other as L tends towards infinity, while remaining distinct for each finite value of L. Here, L must be interpreted as the number of shocks of *alien particles* with the particles composing A in a finite time-interval. In some sense, the Quantum Mechanics distribution $\{p'(L, k): k \in \mathbf{Z}\}$ appears as a limit law, so that the description of the phenomenon given by a causal process should provide a more accurate description of the behavior of A within a short finite time period. According to this interpretation, we consider that among the three candidates of Selleri, his proposal (3) should be the one to be selected as in error.

By all this, our construction is likely to fulfill the expectations of Dirac, who, as cited by Selleri (see, e.g., the concluding page of [6] expressed the following opinion.

I think it likely that, *in the forthcoming years*, *we will be able to build an improved version of Quantum Mechanics*, *in which determinism will find a proper place. This*, *as a consequence*, *will justify the point of view of Einstein towards this matter*.

4.2. Basic Program for Future Research

The physical existence of a universal cloud of *alien particles* would imply the possibility of bringing new answers to major issues related to *gravitation*. It is well-known that gravitation is subject to *screen effects* without apparent gravitational interaction. In such a setup, it appears as paradoxical with respect to the accepted physical theory that the delay of transmission of gravitational influence may become null or even negative. Only Poincaré had got so far as to speculate on such figures, in order to extend the principle of relativity to gravitation, see, e.g., [2,3]. Unfortunately, he could not find any physical evidence to support his assertions, and his proposal was not given more interest afterwards.

We follow Poincaré's line of thought, by considering that the introduction of a universal cloud of *alien particles* is prone to give the proper answers to the above physical questions concerning the notions of gravitation and inertial mass. We consider, namely, that by combining the principles of *lesser action* and of *entropy maximization* with the above-mentioned cloud of *alien particles*, we may build two complementary forms of statistical mechanics.

The first one of these, which could be denoted as *Quantum Statistical Mechanics*, would differ to some extent from Classical Mechanics with respect to its developments related to material points with small mass, such as that related to *alien particles*. On the other hand, it would come closer to Classical Mechanics for the description of the behavior of material points with large mass (this being defined in the proper way). Quantum Mechanics in the sense given today should represent a simplified version of this model, making use of the usual notions of the Measure Postulate, with Planck's constant, spin, and related notions.

The second form, which could be given the name of *Relativist Quantum Statistical Mechanics*, would differ from Classical Mechanics, both in the setup of material points with small masses, and likewise when such particles have large speeds, of the order of what should be expected for *alien particles*. A simplified version of this theory should be provided by the usual Relativist Quantum Mechanics, which combines the postulates of Feynman with the methods of special relativity theory.

Last, but not least, the addition of a universal cloud of *alien particles* to the framework of Classical Mechanics provides a realistic interpretation of gravitation without the presence of gravitational interaction. The Newtonian model assumes, very simply, that the effects of gravitation are transmitted at infinite speed. Poincaré [2] had foreseen such a phenomenon, with possibly negative delays (see Charreton [3] for details).

What is the real nature of the *alien* (or *ultramondaine*) particles? Must one consider such particles as the result of a mathematical abstraction (which is the only present way to justify fully their existence)? Or do they have some kind of physical reality? Our intuition leads us to think that the answer to this second question might be positive. Even though this is nothing else but a conjecture, we feel that this opinion should come in agreement of the words of Poincaré [7] who pronounced the celebrated sentence:

An empty world does not make sense.

The research program outlined above will certainly need the investment of a number of scientists to give fruit. We hope that the new directions, based on [1] and which have been briefly outlined above, will provide sufficient ground to attract the attention of several researchers in the future. In particular, it seems that most of the investigations made during the last decades on quantum gravitation as well as in the field of strings theory appear to end up into dead ends. This shows the necessity of exploring new directions in this field, and motivates fully the present work.

Raoul Charreton, Mas Capel, June 2009

Note: Translation in English, with some changes, from the French version dated 2008.

Post scriptum, 2011: On the same subject, we have published online [8-12]: Une mécanique nouvelle, essai; Vers un changement de paradigme en physique; Une physique atomique préquantique; Les raies de Lyman et la loi de Titus-Bode; L'origine des forces gravitationnelles et électriques; La nature des ondes électromagnétiques.

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