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The Einstein-Podolsky-Rosen and Bell arguments revisited

(Part II)

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II. Restrictive character of the entire system of Bell's axioms and unfalcifiability of the EPR standpoint

Abstract : *It is demonstrated that all the assumptions in Bell's argument are restrictive from the viewpoint of its possible interpretation as a "no-go-theorem" for local deterministic hidden parameters (HPs) theories. The discussion contains general implications that apply not only to Bell's argument but to any other "no-go-argument" too and indicate the essential irrefutability of the EPR standpoint. Examples from statistical physics are employed as illustrations for existing possibilities that have been neglected in "no-go-arguments" and, in particular, for evincing certain analogies with the de Broglie-Lochak way of reasoning on the effect of measurement on HP distributions. The basic point is that in a hierarchy of HP levels of description of reality (corresponding to a possible infinite complexity of matter structures and properties) there may not exist final, "universal" probability patterns. A quantum mechanical paradox of a somewhat* *unusual nature is considered. Due attention is paid to the potential usefulness of HP reasoning (and -in a correct setting- of "no-go" reasoning too) in microphysics.*

Résumé : *On montre que toutes les hypothèses qui sont à la base du raisonnement de Bell sont restrictives du point de vue de son interprétation éventuelle comme un théorème d'impossibilité pour des théories déterministes à paramètres cachés locaux. La discussion contient des conséquences générales qui s'appliquent non seulement au raisonnement de Bell mais aussi à tout autre raisonnement d'interdiction, conséquences qui aboutissent encore au caractère essentiellement irréfutable du point de vue d'EPR. On donne des exemples de physique statistique afin d'illustrer des possibilités existantes qui ont été négligées dans les raisonnements d'interdiction et, en particulier, pour éliminer certaines analogies avec la manière de raisonner de de Broglie-Lochak à propos de l'effet de la mesure sur les distributions de paramètres cachés. Le point essentiel est que, dans une hiérarchie de niveaux de paramètres cachés décrivant la réalité (correspondant à une éventuelle complexité infinie de structures et de propriétés de la matière), il peut ne pas exister de schéma probabiliste ultime, "universel". On considère un paradoxe de mécanique quantique de nature un peu inhabituelle. On prête l'attention requise à l'utilité potentielle du mode de raisonnement à paramètres cachés (et des raisonnements d'interdiction -à condition de les employer de manière convenable-) en microphysique.*

I. THE RESTRICTIVE CHARACTER OF BELL'S AXIOM (i)

It was shown in Part I (1) of the present paper that Bell's axioms (ii) and (iii) (as formulated in (1)) are restrictive, which fact rules out a "no-go-theorem" interpretation of Bell's argument for deterministic local HPs. Interesting enough, even the apparently most natural axiom (i) (1) turns out to be restrictive. We shall show here why and shall discuss a possible consequence of this.

Axiom (i) postulates the requirement that a hypothetical deterministic local HP theory underlying quantum mechanics must employ HPs λ giving a complete state specification of microsystems. These λ's are inexplicitly regarded as a final step in the description of Nature, so that the relevant HP theory should contain, in itself, an explanation and an algorithm for the construction of a hypothetical normalizable probability density distribution (pdd) $\rho(\lambda)$ that might give account of the quantum probabilities. But does there really exist a "complete state specification" of a physical system ? Examine, say, the case of an "elementary" particle. As mentioned in (1), it may have a complex structure of its own. The "elements" of this structure may have, on their turn, a complex structure of their own and so on ad infinitum. Who can guarantee that this possible system of "wheels within wheels within wheels ..." (in Feynman's words) really has an end in terms of "smallest wheels" that would be able to explain every physical phenomenon and that would obey a basic fundamental distribution $\rho(\lambda)$ (if any exists) beyond which there can be nothing else ? In fact, the absence of such an end must be regarded as the *general case* in physics since no reliable arguments *proving* the converse may really be offered at a given level of description of Nature.

Assume then that the system of "wheels" is endless and no finest possible ultimate HP description of Nature exists (that is, a finer HP description underlies every given HP description of physical phenomena). Let us see now what may be one of the logically admissible consequences of this.

Let the possible different "levels of complexity" in an HP description of Nature be denoted as i, $i = 1,2,\ldots,\infty$ (level i + 1 giving a more detailed description than level i) and let certain properties (e.g. magnetic) of the particle be describable at a given level i = n (and all the next levels). Denote the HPs of, say, the undecayed system (a spin-zero "molecule") at this level as $\lambda_{(n)}$. The complete HP description at level n, however, will be crude from the point of view of the more detailed description at level n + 1. Every HP $\lambda_{(n)}$, for instance, may represent a large class of different HPs $\lambda_{(n+1)}$ at the next level. This finer structure would be "hidden" at the n-th level and a number of processes at level n + 1 would be theoretically and experimentally unnoticeable at n. The important point here is that due to the unknown way (at level n) in which the $\{\lambda_{(n+1)}\}$ -classes are composed and evolve with time at level n + 1 the way in which one would "count" the states $\lambda_{(n)}$ in order to construct an HP pdd $\rho[\lambda_{(n)}]$ at level n may be grossly incorrect, or incomplete, or inadequate for at least a part of the n-level quantities from an (n + 1)- level point of view.

In order to make this statement clearer we shall employ

An illustrative thermodynamical example

Consider a fixed quantity (say N molecules) of a given gas. At the thermodynamical level of description the gas is visualized as a continuous medium the state of which is determined by an arbitrary couple of independent thermodynamical variables, e.g. pressure P and temperature T or volume V and internal energy U, all the other variables being expressible, in principle, as functions of the members of the chosen couple. For instance, if one chooses to work with the couple of variables U,V one may determine, say, the entropy S of the relevant (equilibrium) thermodynamical state with the help of the "caloric" equation

$$(1) \qquad S = S(U,V)$$

derivable from experimental data at the phenomenological level. (Other -in principle known- equations of the kind of (1) are $P = P(U,V)$, $T = T(U,V)$, etc.).

Assume that our gas is enclosed in an adiabatic impenetrable volume V, that is, the gas cannot leak out of the volume and, besides, no heat can be imparted to it through the walls surrounding the volume. An "instantaneous" increase of the volume from an initial value V_1 to a value $V_2 > V_1$ (which ensures constancy of U, i.e. $U_1 = U_2$) will lead eventually, as well known, to a new equilibrium thermodynamical state the entropy $S_2 = S(U,V_2)$ of which is larger than that of the initial state : $S_1 = S(U,V_1) < S_2$. From the viewpoint of probabilities we have here (that is, in phenomenological thermodynamics) an

extreme -and trivial- case in which an initial state (U,V_1) of probability 1 is transformed -also with probability 1- to a final state (U,V_2) so that the statistical weights of (U,V_1) and (U,V_2) as inferred from thermodynamics coincide.

[The thermodynamical description of the process can be preserved, at a will, at all stages of the evolution of (U,V_1) to (U,V_2) by carrying out a large series of small "jumps" of the volume, each jump having a value $\Delta V > 0$, during which process one may have, in principle, well defined values of the thermodynamical variables all the time.]

The increase of S in the above process cannot be explained by phenomenological thermodynamics. For that reason it is just postulated in the said theory (the so-called second law of thermodynamics), while its explanation is left for a "finer HP theory" -statistical thermodynamics. This explanation consists in the statement that, in our case, the initial (classical) state of motion of the N particles enclosed in a volume V_1 (a new concept replacing the old one of a gas *entity* in a volume V_1) is, in a sense, much less probable than the final state of the N molecules (in V_2). Really, employing a well known definition (cf. e.g. (2)) we have (up to an inessential constant factor)

$$(2) \qquad S_i = S(U,V_i) \sim -\int \rho_i(p,q) \ln \rho_i(p,q) dp dq, \quad i = 1,2,$$

where $p = (p_1,\ldots,p_{3N})$ and $q = (q_1,\ldots,q_{3N})$ stand for the 3N momenta and 3N coordinates of our N particles, while ρ_1 and ρ_2 are the normalized pdd's at $q_j \in V_1$ and $q_j \in V_2$, correspondingly $(j = 1,2,\ldots,3N)$. In the case of a microcanonical ensemble of thermodynamically equivalent copies of our N-particle system $(E \leqslant U \leqslant E + \Delta E, \ \frac{\Delta E}{E} \ll 1)$ a postulate of Gibbs says that $\rho_i = (\mathrm{const})_i$ $(i = 1,2)$, so that

$$(3) \qquad S_i \sim \ln \rho_i, \qquad i = 1,2.$$

Denoting as $v_{ph,i}$, $i = 1,2$, the volume in the 6N-dimensional phase space occupied by the microstates of the ensemble members we obviously get under the above conditions

$$(4) \qquad \rho_1 v_{ph,1} = \rho_2 v_{ph,2} \; (=1),$$

so that

$$(5) \quad S_2 - S_1 \sim -\ln(\rho_2/\rho_1) = -\ln(\rho_2 v_{ph,1}/\rho_2 v_{ph,2}) = -\ln p_{1|2} > 0,$$

where $p_{1|2} = v_{ph,1}/v_{ph,2}$ is the probability to find an individual state (p,q) in $v_{ph,1}$ given an admissible phase volume $v_{ph,2}$ of variation of (p,q) (at $V_1 < V_2$ we certainly have $v_{ph,1}/v_{ph,2} < 1$). We thus have here a physical magnitude (the entropy increase $\Delta S = S_2 - S_1$) the value of which is determined just by the above *conditional probability* $p_{1|2}$, which is undefinable in phenomenological thermodynamics. The same applies to other magnitudes, say $T_2^{-1} - T_1^{-1} = \frac{\partial}{\partial U}(S_2 - S_1)$ (as $T_i^{-1} = \partial S(U,V_i)/\partial U$).

In such a way statistical thermodynamics explains both why one would (incorrectly from the viewpoint of entropy-increase explanation) assign the same statistical weights in phenomenological thermodynamics to the initial state of the system (in V_1) and to the final state (in V_2) and why entropy actually increases : The former is explained by the fact that a given number of microstates (perceived as the same macrostate in phenomenological thermodynamics), all in a configuration volume V_1 due to specific initial conditions, evolve into the same number of states in a volume $V_2 > V_1$. The latter is explained by the fact that, in a V_2-microcanonical ensemble, it is less probable that a given physical system would be found in a V_1-state than in a V_2-state, so that we have now quite a different criterion for evaluation of statistical weights that gives entropy variation. In other words, phenomenological thermodynamics can describe "deterministically" the variation of entropy (and other magnitudes) but cannot explain the intimate mechanism neither directly nor through its inadequate "phenomenological probabilities". The said mechanism is explained by statistical thermodynamics through imbedding relevant conditional probabilities into the apparently unique and "deterministic" phenomenological states, which probabilities give account of the fact that a seeming entity actually consists of N different entities, the microscopic initial conditions for which encompass only a part of all the possible states in given physical conditions (in our case -in a volume $V_2 > V_1$).

The above example, employed just for *illustrative purposes*, clearly shows at the same time that Bell's argument disregards the following possibility. In an infinite series of HP levels of description of Nature one may

(a) be able to find, at a certain level n, local HPs $\lambda_{(n)}$ that describe uniquely the evolution of a given system (that is, the transition $\lambda_{(n)\text{initial}} \rightarrow \lambda_{(n)\text{final}}$) and give a deterministic picture of the variation of, say, its magnetic properties ;

(b) be totally unable to determine correctly at n adequate $\lambda_{(n)}$-dependent probabilities that may give account of certain numbers, e.g. experimentally observable correlations, etc (by analogy with the above example such correlations may be obtainable, e.g., from certain conditional probabilities imbedded into seemingly unique n-level states).

We thus see that the problem of the construction of a local deterministic HP theory at any level n of description of Nature may consist of two separate problems :

(a') The basic problem of finding the HPs that would describe the behaviour of an individual physical system s from an n-th-level-of-complexity viewpoint. (EPR have in mind precisely this problem in their famous argument).

(b') The (quite different) problem of finding the n-level HP probabilities and the correct way of their employing.

The latter consequence of our consideration means that a straightforward use of formulae of the kind, say,

$$(6) \qquad P(a,b) = \int \rho[\lambda_{(n)}]A[a,\lambda_{(n)}]B[b,\lambda_{(n)}]d\lambda_{(n)}$$

for the determination of two-particle correlations P(a,b) (cf. (1)) with the help of a parameter-independent normalizable pdd ρ at level n would, generally, be naive even when such a ρ would seem to be derivable from certain experimental facts at level n : This may correspond, as stressed above, to an incorrect or inadequate way (from an(n + k)-viewpoint, k =1,2, ...) of assessing at level n other relevant probabilities (e.g. the ones determining the magnetic properties). One would then face the task of contriving a system of axioms at some level n + k, k = 1,2,..., that would guarantee correct numerical results for the stochastic quantities in question. The actual construction of the said system of axioms will entail, for the particular case examined, the replacing of eqn. (6) with an equation of the kind

$$(7) \qquad P(a,b) = \int A[a,\lambda_{(n + k)}]B[b,\lambda_{(n + k)}]D_{a,b}\lambda_{(n + k)},$$

where the "differential" $D_{a,b}\lambda_{(n + k)}$ is an abstract symbol for the way in which the statistical axioms may work in our case (recall that, say, pertinent parameter-dependent conditional probabilities may underlie any given $\lambda_{(n)}$). Its parameter-dependence will not, generally, be connected with the introduction of any nonlocality : in the local variables w', w" of Part I (1) (now at level n + k) eqn.(7) may acquire the form

$$(8) \quad P(a,b) = \int r[a,b;w'_{(n + k)},w''_{(n + k)}]C[w'_{(n + k)}]C[w''_{(n + k)}] \, dw'_{(n + k)}dw''_{(n + k)}$$

where, as pointed out in (1), locality is ensured by the independence of the displays $C[w'_{(n + k)}]$,$C[w''_{(n + k)}]$ of the measuring instruments M', M" of the parameters a,b, the parameter-dependence of r having no relevance to the problem of locality (or its absence) and being, generally, *essential*, i.e. violating Bell's inequalities. Such r's may possibly appear due to reasons discussed in Sections 6 - 8 of (1) or reasons that are nonobvious at present. In any case, *the irrefutability of the EPR basic standpoint would be a consequence of the fact that in an infinite HP-level hierarchy there are in principle no universally valid ultimate probability patterns and any next HP level may radically change the concept of pertinent probabilities, so that one would have at a given level n either an EPR description of reality in combination with correct probabilities or unfalcifiable potentialities for such a description (if this was not the case at n) at the next HP levels.*

2. THE DE BROGLIE-LOCHAK ARGUMENT REVISITED

The natural possibility of employing at a given level n parameter-dependent pdd's in formulae of the kind of (8), etc, has already found its realization in physics : Once again, this is the case of statistical thermodynamics which is the "HP theory" of phenomenological thermodynamics, so we shall return here to the above analogy. Indeed we mentioned above that in a scheme containing an infinite series of HP levels the general consideration in the present paper applies mutatis mutandis to the arguments discussed in Sections 6 - 8 of (1). It would be useful to examine here the case of the de Broglie-Lochak way of reasoning (3,4) from the viewpoint of the said scheme due to the close similarity of this argumentation in the case of interest with the familiar statistico-thermodynamical reasoning and obtain certain specific motives for asserting the fundamental nature of formula (8) and the like.

As well known, the pdd's $\rho(p,q,t)$ employed in statistical thermodynamics depend on certain parameters too that take into consideration, in particular, the macroscopic environment of the N-particle mechanical system. For instance, a classical N-particle system s in a volume V and in an equilibrium contact with a thermostat obeys a pdd (2)

$$(9) \qquad \rho_{N,V,T}(p,q) = Q^{-1}(N,V,T)\exp[-H(p,q)/k_BT)],$$

where H is the Hamiltonian, k_B -the Boltzman constant, and Q-the partition function. At fixed N and V the basic ρ-determining parameter is T and the mechanical states (p,q), belonging to one and the same set of possible values, will be assigned different statistical weights $\rho(p,q)$ depending on the values of T. A given T, at that, corresponds to a macroscopic environment of s that is incompatible with the one corresponding to any T' $\neq$ T (a thermostat, by its very definition, may have only a fixed temperature), so that the different ρ_T in statistical thermodynamics correspond to *physically incompatible experimental situations*.

The type of the parameter-dependence of the above ρ's is easily undestandable, in principle, in the picture containing a series of HP levels. Indeed at any level n of description of Nature one must, generally, take into consideration too the properties of physical environments in a given experiment and this applies to relevant ρ's as well. However, at level n, we do not have at our disposal concepts that may be more fundamental than $\lambda_{(n)}$, $\lambda_{(n-1)}$, etc, so that environment in particular can be described using variables at the given level n or the preceding more "crude" levels n - 1, n - 2, etc. In the particular case examined (N,V fixed) the postulates of statistical thermodynamics involve environment description at the more crude level of phenomenological thermodynamics. (A variable N will give a "finer" parameter of ρ at the next level -statistical thermodynamics).

One may easily notice the close analogy between the above well known facts and de Broglie's ideology (3,4) concerning the interpretation of quantum mechanics. According to this interpretational approach one must bear in mind the possible difference between present, predicted, and hidden HP probabilities since quantum mechanical probabilites may in principle be explained with the help of predicted HP probabilities that are evinced in the actual process of measurement, which may possibly radically transform the initial hidden HP distribution. For Bell's experimental situation the just said means that observable HP distributions appear after the interaction of subsystems S' and S" with the "magnetostats" (measuring instruments) M' and M". In total analogy with statistical thermodynamics these measured distributions ρ_m will, generally, depend on the concrete couple (a,b) of orientations of the "magnetostats" M' and M", the different couples (a,b) corresponding to *physically incompatible experimental situations*. (That is, the orientations (a,b) in mutually incompatible correlation experiments play in principle the same role as, say, the temperature T of incompatible thermostats despite the physical difference of the specific mechanisms). As pointed out in (1), Section 6, these ρ_m $(a,b;w'_m,w''_m)$ (subscript m denoting here quantities taken after the "analysing stage" of the measurement process) may coexist with both locality and determinism. The only difference between the said case and the one containing a hierarchy of HP theories is that in the latter case we have additional degrees of freedom. Namely, it is not obligatory to find an explanation of the way in which hidden probabilities are transformed into predicted ones at the same HP level n at which one would obtain for the first time the possibility to give a deterministic picture of the evolution of an individual HP state $\lambda_{(n)\text{initial}}$ into a state $\lambda_{(n)\text{final}}$, giving account of the magnetic properties of the particle. In other words, the correct explanation of pdd transformations may be "additionally hidden" into the higher levels n + 1, n + 2,... of a possibly infinite HP hierarchy.

In such a way a concrete physical idea (3,4) (environment influence) has a natural counterpart in physics in terms of employing parameter-dependent distributions in eqns. of the kind of (8) in (classical) statistical thermodynamics (in which the relevant "generalized differential" has the canonical form $D^{\lambda}_{N,V,T}(p,q) = \rho_{N,V,T}(p,q)dpdq$ -cf. eqn. (9)). The discussion in (1) and the present paper provides an additional justification and enlarges the possibilities of the idea (from the viewpoint of HP hierarchies) by detaching the basic problem of HP definition and evolution from the one of HP statistical properties.

The considerations in the present two-part article contain a number of quite general philosophical implications which will be discussed below.

3. PHILOSOPHICAL IMPLICATIONS

The content of this paper is in harmony with a philosophical credo of many (shared by the present writer too). Somewhat vaguely this credo may be formulated as follows: *Any fundamental philosophical standpoint is irrefutable.*

But what does "fundamental philosophy" really mean ?

I shall propose a personal working definition. Namely, a *fundamental philosophical outlook* of Nature is a most general doctrine about the essence of physical laws, that is, an outlook on the nature of the world we live in that does not rest on concrete specific assumptions.

For instance, a fundamental outlook from the above viewpoint is the concept of indeterminism as the essence of physical laws. The opposite -also fundamental- concept is that a (local) deterministic description of physical phenomena is always possible. (Such, to my understanding, is the EPR thesis).

A consequence of our postulate is that one may accept as a personal outlook any one of the above incompatible concepts (or a certain negation or combination of both) but any attempt at invalidating the alternative basic concepts would *ultimately* be futile.

Once again from our point of view the Copenhagen doctrine on the interpretation of quantum mechanics does not represent a basic philosophical concept : Besides the concept of fundamental indeterminism, it contains the concrete assumption (treated there as a *fact*) that time-position and energy-momentum variables are mutually exclusive quantities in the quantum world. We shall demonstrate in a future work (by examining concrete quantum wave functions) that what we have here is not, generally, a fact but just an allegation.

The discussion in the end of Section 1 offers a definite "mechanism" for the irrefutability of the EPR basic viewpoint (non-final nature of any HP probability pattern in an infinite HP-level hierarchy). Consequently, there exist, *in principle*, possibilities for its realization in physical theories. The problem is to actually *construct* pertinent deterministic HP theories explaining experimental facts. The natural impediments that would be encountered in the way should not be treated as giving evidence of the invalidity of the EPR philosophy : It is well known that the construction of basic physical theories is an extremely difficult task in any case.

We have witnessed the failure of *all* the proposed "no-go-theorems" to convince the physical community as a whole in the impossibility of HP theories. There exist quite clear-cut reasons for this. Namely :

(A) The natural order of things and the actual goals of physical theories are totally neglected by the authors of such writings.

Indeed a given nontrivial physical theory, aiming at the explanation of a set of experimental facts, only inexplicitly rests on the philosophical standpoint of its creators. The validity of the theory is assessed with the view of its agreement or disagreement with experiment and the refutation of a theory is in fact a refutation of a given theoretical model and not a given philosophy. Really, a philosophical attitude is not a physical magnitude, it has no numbers attached to it and the refutation (or confirming) of certain predicted numbers in the course of experiments cannot invalidate (or confirm) a philosophical standpoint which transcends physical theories. The same applies to the attempts of a theoretical invalidation of a philosophical viewpoint since the theoretical "no-go-arguments" are either of a physical or mathematical nature (or a combination of these), so that the concept which they try to attack invariably remains beyond their reach, or of a philosophical nature -but (cf. also (¹)) philosophical aternatives rest on mutually exclusive logics and can be just shared or not (which certainly has nothing to do with any "refutation").

(B) The very assumptions (which at a given moment seem to their authors to be the most general and natural requirements for every possible physical theory) on which a "no-go-argument" rests invariably turn out to be restrictive or just unconvincing to a number of people.

For instance, Bell himself found unconvincing (⁵) all the "no-go-theorems" preceding his own one and this should have been a serious warning for him about the destiny of any argument of this sort. But he proposed a "no-go-theorem" of his own -which may be regarded as a typical example of the restrictive nature of all such arguments.

How can the author of a "no-go-argument" convince the physical community that he has indeed proved a theorem resting on most general, universally valid assumptions and invalidating a basic philosophical concept ? In these arguments we have in fact the "word of honour" of their authors that their assumptions are certainly (and "evidently") the most general possible ones. It would be relevant to point out here that a different field of science -mathematics- has witnessed the fiasco of numerous "universally valid" ideas concerning the nature of mathematics and its possible relation to physics, even when their proponents were people as Hamilton, Hilbert, and others of that calibre. Highly instructive facts of this kind may be found in an excellent book by M. Kline (⁶) and one must really remember his warning (end of ch. IV) that one should be most careful precisely when one is quite certain about the validity of a given "truth" since not only the achievements of science but the limitations of one's own way of thinking too may underlie one's certitude.

There are thus no reasons to regard any "no-go-argument" as a kind of a theorem determining the future course of physics : These arguments rest on unproved assumptions which cannot be proved, at that, without contriving other unproved assumptions, etc, etc. There exists just one sense in which such arguments can be useful. Namely, they have to be regarded in fact as *warning arguments*, showing what specific assumptions in HP theories have little chances for success in describing Nature.

Speaking about the possible usefulness of "no-go-arguments" in physics, we cannot circumvent too the question of the usefulness of HP reasoning in physics. As pointed out by Lochak (⁴), it was precisely de Broglie and his school that gave birth of the idea (quite fashionable nowadays) of the importance of nonlinear effects and equations in quantum mechanics. In such a way different approaches (e.g. to nonlinearity) may serve the same goal and attemps at invalidating any one of them on the basis of "general" allegations is, at least, senseless. There is, however, another example in favour of the same idea and its consideration leads to

A quantum mechanical paradox of a strange kind

As well known, the Copenhagen doctrine about the nature of microphenomena is based on the idea of the existence of unpredictable and uncontrollable effects of the (inevitably classical) measuring apparatus on physical phenomena in the microworld. This idea rests on the concept of the equal order of magnitude of the physical effect itself and the influence of the measuring instrument on it (cf. e.g. the well known treatise by von Neumann), and Heisenberg's uncertainty relations are treated as its mathematical expression. More precisely, these relations are visualized as the consequence of the instantaneous exchange of uncontrollable, always finite, indivisible quanta between the concrete physical system and the experimental set-up measuring it, the unpredictable perturbations affecting either the time-position or the energy-momentum characteristics of the said system. The Copenhagen doctrine thus has two immediate consequences :

(1) A physical microsystem may be described in two mutually exclusive ways -either in terms of time-position variables or in terms of energy-momentum variables.

(2) There does exist a *finite limit* of divisibility of matter that is determined in a natural fashion by the existence of uncontrollable *finite* quanta in the process of measurement. The presence of such a limit is interpreted as an important philosophical asset of quantum mechanics (⁷) (in fact, of its Copenhagen interpretation, but this interpretation was "automatically" identified with quantum mechanics itself and the critiques against the said interpretation -as critiques against the content of quantum mechanics). In such a way quantum mechanics was perceived as the theory of the smallest possible matter entities (electrons, protons, photons) that must be described only in the simple terms of energy-momentum, or of the

alternative time-position variables.

The description of the mentioned "entities", however, did not turn out to be that simple and, as well known, hadrons were endowed with a quark-gluonic structure intended to give account of their quite complex inner properties. From the viewpoint of the original Copenhagen philosophy this more detailed picture represents in fact an HP theory, at that an HP theory of the "worst" kind, namely, containing HPs that are *directly unobservable in principle*. Indeed the basic point in the mentioned theory is the employing of the quark concept for the explanation of certain properties of hadrons (e.g. scattering cross-sections) and, at the same time, the contriving of an adequate "confinement mechanism" that might explain why free quarks are not observed in Nature. (In other words, there exists only indirect evidence about "quark HPs" of hadrons).

In such a way, in the presence of a pressing necessity, the implications of the Copenhagen tenet were quietly put "under the carpet" and the outlines of a physical theory appeared that gives a more detailed picture of the structure of matter than the one initially considered as the only possible. Up to here there is no paradox but just a natural development of science which inevitably breaks any restrictive frameworks established by certain personal philosophies. The paradox comes, however, when a particle physicist is asked whether HP theories are possible in microphysics : In practically all cases the answer would be "no, since rigorous theorems rule them out".

But in this case too HP theorists have made an important step in the "inner-structure-direction" as orthodox theorists and this step was made, once again, much earlier than the "big bang" of gauge theories occurred. Indeed it was an idea of de Broglie forwarded as early as 1924 (cf., e.g., (4,8)) to introduce an "internal clock" (in other words -international vibrations) into the microparticle in order to explain the peculiarities of its motion in the assumed field of its own pilot wave. Internal vibrations, however, imply inner structure since there can be nothing internal in a point. If one employs here the well known analogy of an airplane piloted by radiosignals, then it is certainly the complex inner machinery of the airplane that makes the driving process possible in the field of such low energy signals (a piece of rock would certainly be practically insensitive to them).

It is thus only old prejudice and the illusion that rigorous "no-go-theorems" actually exist that prevents different approaches in physics from mutually enriching each other in their pursuit of a common goal.

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