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FACTS AND TIME IN QUANTUM MECHANICS: A STUDY IN PHENOMENOLOGY AND PRAGMATICS

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Abstract: The concept of well-defined and mutually exclusive objective facts has no counterpart in the formalism of standard quantum mechanics. Bypassing decoherence theories, we then inquire into the conditions of use of this concept of objective fact, and find that it is grounded on the possibility of making reference to spatio-temporal continuants and permanent properties. Since these conditions are not fulfilled within the quantum paradigm, one must look for appropriate substitutes. Two such substitutes are discussed. The first one is phenomenal fact (or pure appearance), whose relevance to quantum physics is evaluated in the framework of Husserl's phenomenology. The second substitute is intersubjective agreement, which can be disconnected from objectivity *stricto sensu*, as quantum mechanics seems to require. A study of intersubjectivity in terms of the pragmatics of language is undertaken. This study is applied to both Everett's symbolism of memory brackets and Bohr's transcendental remark that description of scientific experiments cannot dispense with ordinary language.

Keywords: Quantum mechanics. Measurement problem. Factuality. Phenomenology. Time. Present. Everett's interpretation.

FATOS E TEMPO EM MECÂNICA QUÂNTICA: UM ESTUDO DE FENOMENOLOGIA E PRAGMÁTICA

Resumo: O conceito de fatos objetivos bem definidos e mutamente exclusivos não tem contraparte no formalismo da mecânica quântica padrão. Desconsiderando as teorias de decoerência, investigamos o uso desse conceito, e constatamos que ele está fundamentado na possibilidade de se fazer referência a propriedades permanentes que persistem no espaço-tempo. Uma vez que essas condições não são satisfeitas pelo paradigma quântico, devemos indagar por substitutos apropriados. Dois de tais substitutos são aqui discutidos. O primeiro é o fato fenomênico (ou pura aparência),

cuja relevância para a física quântica é avaliada no contexto da fenomenologia de Husserl. O segundo substituto é a concordância intersubjetiva, que pode ser desconectada da objetividade *stricto sensu*, como a mecânica quântica parece requerer. Um estudo da intersubjetividade em termos da pragmática da linguagem é delineado. Este estudo é aplicado tanto ao simbolismo de Everrett das configurações (colchetes) de memória quanto à observação transcendental de Bohr de que a descrição dos experimentos físicos não pode dispensar a linguagem ordinária.

Palavras chave: Mecânica quântica. Problema da medição. Fatualidade. Fenomenologia. Tempo. Presente. Interpretação de Everett.

1. INTRODUCTION

The present investigation arose long ago from a sentence in a paper of Bernard d'Espagnat [1990]. Here it is (in shortened version): "Within standard quantum mechanics, (there are) no 'really existing' facts".

At first sight, this sentence looks like a joke. Indeed, how could a theory preclude facts? After all, the very minimum one is entitled to require from a theory, is to describe facts, and to provide as much information as possible about future facts, given a set of past and present facts. A theory must *concern* facts; it is thus beyond its scope to decide whether or not facts should *exist*. One should require at least that its structure is not incompatible, at our scale, with the notion of well-defined and mutually exclusive facts. It was the role of Decoherence theories to show this for quantum mechanics. But since the meaning of decoherence is still an object of fierce discussions[1], I wish to bypass it for a while and rather turn to the broader and philosophically challenging issue of the status of facts in physics.

Now, once the initial surprise triggered by d'Espagnat's sentence has died down, one must start thinking a little harder. The sentence just quoted is not intended as an univocal and unescapable conclusion. It offers at least two possibilities of sorting out the situation.

[1] Bitbol [2009, 1997], Mohrhoff [2001], Zurek [2003].

To begin with, the second part of the sentence does not say flatly "there are no facts", but "there are no 'really existing' facts". This suggests that there might be more than one definition of the word "fact", according to its relations with whatever is meant by 'real existence'. Some of these definitions could then turn out to be compatible with the specifications of quantum mechanics. This is the reason why, in the next section of this paper, I will try to address the question: "what is a fact?".

But let me also scrutinize the first part of the quoted sentence. There, d'Espagnat does not refer to quantum mechanics in general, without any qualification, but only to *standard* quantum mechanics. This clearly indicates, when taken in conjunction with previous parts of d'Espagnat's paper, that some non-standard versions of quantum mechanics accommodate the idea of 'really existing' facts. Therefore, in a further section, I will inquire into whether it is actually worth supplementing standard quantum mechanics with any kind of additional device, just for the sake of recovering a traditional concept of 'really existing' fact. Renouncing this conceptual facility will force us to examine alternative metaphysical pictures, and eventually to engage in a critique of metaphysics.

2. MATTER OF FACTS

What is a fact? We can distinguish *three* meanings of the word "fact", corresponding to the three persons of verbs. Let us for instance consider the following statement of a fact, uttered by a scientist: "there is a 1 on the dial of this apparatus". This statement can be apprehended in three ways.

1. One may take its third-person status at face-value and accept that it just *refers to* an apparatus "out there" and to its definite state[2].

[2] When it is so understood, the statement is usually said to refer to "an objective event" occurring in the world, rather than to a "fact".

2. One may alternatively think that the statement has a performative status; that in other terms it aims at arousing intersubjective (second-person) agreement about the measurement outcome 1.
3. One may finally consider that it *expresses* something about what the speaker is perceiving; in this case, it is apprehended as a disguised first-person statement and it has a reflective status. We shall successively discuss these three possibilities, but in a different order.

A) Phenomenal facts

The reflective meaning of the word "fact" (point 3 of the previous list) deals with what is presently experienced by the speaker, or at least with a conceptualized fraction of this experience. *Phenomenal facts,* as we shall call them, are directly expressed by stating partial, abstract, and more or less interpreted contents of the overall present experience, in sentences using the *first person*, and/or spatio-temporal indexicals; e.g. "*I* am hearing the thunder here and now", or "*I* am seeing that the pointer of my experimental device is directed towards the digit 1 rather than 0", or (at a higher level of interpretation) "*I* am realizing that the observable 'angular momentum' measured on this atom has the value 1 ".

Even though phenomenal facts are abstracted from present experience, they retain its character of immediacy and of self-evidence. It must however be kept in mind that *this character of immediate self-evidence* cannot be communicated[3]. It cannot be communicated to other people, except perhaps through the substitute of an act of faith or empathy. It cannot even be communicated to *me* later on, when the thunderstorm is

[3] One may of course provide*evidence* to other people, that something has happened. However, this does not mean that we can share what I called the "phenomenological character of evidence" (whose introspective correspondent is the "feeling of evidence") with other people.

over, or when I have left the lab., except through the belief that my memory is reliable. Certainty of *having seen* something is definitely to be distinguished from certainty of *seeing* it. The above lack of communicability can be construed analytically, as arising from the grammar of the indexicals "I" and "now". It can also be construed phenomenologically as pertaining to what "makes itself manifest" [Wittgenstein (1961)] without lending itself to ostensive definitions.

Now, what can be said about the relations between quantum mechanics and phenomenal facts? To begin with, quantum mechanics is a physical theory, and as such, it can by no means contain immediacy, evidence, certainty, or any other correlate of first-person account, within its field of description. However, like any other scientific description, quantum mechanics ultimately relies on phenomenal grounds, and it should therefore be concerned with providing a *connection* between phenomenal facts in some (very indirect) way.

What kind of connection is this, and how can it be expressed? Many scientific theories have the following type of first-person *conditional factual* sentence among their indirect consequences: "*If* I have seen a flash of lightning, and if I have ascertained the absence of any soundproof barrier between me and the flash (no-obstacle condition), *then* I will hear the thunder". More professionally, the basic type of sentence one is justified to expect from a physical theory reads as follows: "If I have adequately prepared the object O and the experimental device E, namely if I have observed such and such phenomena connected with the satisfactory completion of this preparation, then I will see later on that the pointer of my apparatus is directed towards the digit 1, and not towards 0". But this is not yet close enough to actual experience. In view of the incommunicability of immediate experience, which also concerns *the successive states of a single observer*, one should rather condense the previous sentences in present-tense form: "If I have the certainty of *having observed* such and such phenomena connected with the good completion of the experimental preparation, and if I am *now* checking the result of the experiment, then

I *am seeing* that the pointer of my apparatus is directed towards the digit 1, and not towards 0". In the latter sense, one can say that the physical theory provides *conditional* information about the existence of some internal abstract connections within present experiences, including memories. It primarily provides conditional information about the existence of internal connections *within* a single experience, or within a single global phenomenal fact, rather than conditional information about the existence of connections *between* successive phenomenal facts. But in general, as everybody knows, quantum mechanics does not even establish strict one-one correspondences of this kind. It provides a weaker link, of probabilistic nature.

Let us then examine the special way phenomenal facts and their internal connections are expressed quantum-mechanically. This requires to give an innocent look at some elementary features of the formalism of quantum mechanics, in order to connect them to phenomenal facts.

The *initial* phenomenal fact, namely the one referring to the satisfactory completion of the experimental *preparation,* is expressed by an eigenvalue x of some observable X. The probabilistic information I have concerning the phenomenal end result of any possible experiment following the preparation (provided a no-obstacle condition is fulfilled) is then contained[4] in the eigenvector $|x\rangle$ associated with x. Let us now suppose that an experiment has two possible phenomenal outcomes: "I am seeing that the pointer of my apparatus, used to measure angular momentum of atoms, is directed towards the digit 1" and "I am seeing that the pointer of my apparatus, used to measure angular momentum

[4] This way of expressing the content of a state vector is not meant to sketch a (phenomenalist) *interpretation* of quantum mechanics. It just states what may be considered as a minimal aim of any interpretation of quantum mechanics (and of any other physical theory as well), namely to account for certain abstract connections within appearance. The problems which arise from the use of higher-level reference to objects, pointers, apparatuses, interactions etc. in the very description we give of phenomenal facts, will be discussed later on, in connection with pragmatics.

of atoms, is directed towards the digit 0", respectively associated with the eigenvectors $|1\rangle$ and $|0\rangle$ of the corresponding observable. Then, the vector $|x\rangle$ is written as a linear superposition:

$$|x\rangle = c_1|1\rangle + c_0|0\rangle$$

This is not tantamount to a conditional statement of existence of some strict connection internal to phenomenal experience. Instead, this only states the *probability* of my seeing 1 or 0 (respectively $|c_1|^2$ and $|c_0|^2$), in a series of situations wherein I have the certainty of having observed a given set of preparatory phenomena.

Let us summarize these remarks:

1) Quantum mechanics, like any other physical theory, does not refer directly to a full content of experience, but it is obviously not incompatible with the mere existence of pure experience and it ultimately connects with it.

2) Classical mechanics at least provides *univocal conditional* statements about certain abstracted contents of experience. By contrast, quantum mechanics provides no non-trivial version of such *strict* conditional statements.

As it is well known from Von Neumann-like treatment of the measurement processes, we don't change this situation if we call in the information about the phenomenal outcome of any second-order or third-order experiment which might be performed either on the configuration of a tape recorder connected with the apparatus, or on my own brain after I have read off the information.

To display this first-person version of the well-known *measurement problem* of quantum mechanics, let us go further on:

Before the measuring interaction between the object and the apparatus connected to the tape recorder has effectively taken place the information about the possible phenomenal outcome of an experiment bearing (say) on the tape recorder is described quantum mechanically by a vector $|\phi\rangle$. The information I have about the possible phenomenal outcome of

the first-order experiment is still expressed by $|x\rangle$. Then, the *initial* joint information is $|x\rangle|\phi\rangle$. In view of the linearity of the time-evolution law, the final joint information (after the measurement interaction has taken place) is given by:

$$c_1|1\rangle|\phi_1\rangle + c_0|0\rangle|\phi_0\rangle$$

The latter state vector does not yield any univocal conditional statement about the existence of a *joint* phenomenal fact bearing both on the first-order experiment *and* on the second order experiment (the one which concerns the tape-recorder). However, something new and interesting can be derived from the previous analysis: "If I am *now* checking the result of the last-order experiment (say the one bearing on the tape-recorder), and if I *am certain of having seen* the pointer of the apparatus directed towards the digit 1, then I *am seing* that 1 is printed on the tape-recorder". This is a non-trivial conditional statement about the *internal relational structure* of certain phenomenal facts. The main difference with corresponding statements of classical theories is that the boundary between the condition and the conditioned has shifted. The condition has to encompass part of what is called the outcome, and not only the preparation.

B) Objective facts

Obviously, no one can be satisfied by the previous first-person account taken in isolation. To see why this is not enough, let us ponder about the first (daily life) type of factual conditional sentence we considered: "If I have seen a flash of lightning, and if I have ascertained the absence of any soundproof barrier between me and the flash, then I will hear the thunder". What if *I* have *not* seen any flash of lightning and/or if *I* have *not* ascertained the absence of soundproof barriers? It may happen that I don't hear the thunder, but it may also happen that I do hear it. Thus, if I wish to get better theoretical predictions, I must look for conditions having a stronger and more constant link with the

conditioned fraction of the phenomenon. The first step in this direction amounts to relying on intersubjectivity. The condition "If I have seen a flash of lightning..." is more efficiently replaced by "If somebody has seen a flash of lightning..." whose affirmative content ("somebody has seen a flash of lightning") can even be checked by me *a posteriori*, after I have heard the thunder. But here again, the condition may fail to encompass every possible subsequent happening. It may happen that I am hearing the thunder (and that most people are hearing the thunder), even though no one has seen a flash of lightning before. The final step is thus to take the element of semantic reference which is implicit in the very use of the names "flash of lightning" or "thunder" at face value, and to suppose that these names are directed towards *third-person* entities which rigidly condition each other. These entities should allow one both to state a positive factual conditional sentence (such as: "If X has occurred, then Y will occur"), and its negative counterpart ("If X has not occurred, then Y will not occur"). They should even legitimate a conjunction of past-tense positive and negative statements on a factual/counterfactual basis: (e.g. "X and Y have occurred" and "if X had not occurred, then Y would not have occurred either"). The latter conjunction affords a counterfactual definition of causation.

However, everything is not yet settled at this point, for the above-mentioned third-person entities can be construed either according to a phenomenalist doctrine or according to a realist one. The phenomenalist doctrine amounts to extending the intersubjective move to infinity. Even if no one is aware of the initial condition of some phenomenal fact, the improved phenomenalist assumes that there is an infinite number of potentially available phenomenal facts, some of them enclosing the condition. This type of conception was advocated by J.S. Mill [1865] and B. Russell [1979], and it is obviously reminiscent of Leibniz' monadology. Its main defect is that even though it multiplies the subjective viewpoints, it makes intersubjective communication unintelligible (except, may be, in terms of simulation of each other's situation [Goldman, 1992; Greenwood, 1999]). The potentially available

phenomenal facts are indeed *public entities,* but in a very peculiar sense: they can be *experienced* by anybody, but they cannot be *shown* to anybody else.

Realist doctrines primarily aim at filling this gap by positing a realm of public (objective) entities which can be spoken about after an initial act of ostensive definition has been performed. This provides a kind of "substantial" ground to intersubjective communication. However, as Schrödinger [1961] noticed (along with his post-kantian approach), such a ground cannot be considered as an *explanation* of the possibility of intersubjective communication and agreement, but only as a restatement of intersubjective agreement in more general terms. Indeed, what could one *say* about the posited "real" entities, beyond the plain statement that they provide a common ground for intersubjective agreement through their "causing" similar appearances to occur in several subjects, and through their being therefore apt to be referred to in an interlocutionary situation?

At any rate, if the realist account is to be brought to completion, one has then to decide which type of entity it construes as primary. The candidates are events, properties and objects (or spatio-temporal continuants). Events as well as permanent properties of objects may be construed as members of the wider class of *objective facts*. They are both able to underpin intersubjective communication, and much work has been done to show that events can be referred to through singular terms in the same way as permanent objects [Davidson D. (1980)]. However, the need for intersubjective communication is not the only one to be fulfilled, and this may help us in making our choice between the former candidates.

As previously pointed out, the character of evidence of a phenomenal fact I am *now* experiencing cannot even be said to be *fully* communicable to *myself* later on. Thus, if I wish to secure the possibility of sharing something of the immediacy of my present phenomenal experience, not only with the people who are co-present at an event, but also with *me* later on and with any other people who were *not* co-

present at some event, I need either to shift my attention exclusively onto permanent properties of objects, or else to embody transient events in irreversibly modified properties of objects, which may be considered as the *traces* of these events maintained throughout subsequent history. I need in other terms to *provide evidence*, toying purposedly with both the phenomenological and the legal sense of the word "evidence": not only to claim that I am certain of having seen something, but also to *show* a permanent "exhibit".

The first shift amounts to limiting statements of objective facts to permanent properties. For instance: "Gold is yellow; this is a fact". But one may wish to accommodate weaker statements of objective facts, namely statements of events. For instance: "An earthquake occurred in Skopje in 1963; this is a fact". In this case, we must perform the second kind of shift by adding the words: " … just listen to the testimony of eyewitnesses[5], or look at the seismical records, or see the pictures in archive etc... ". Let us then analyze more closely the difference between the two types of statement referring to objective facts. In the first statement, "Gold is yellow", the fact arises from a single property of an object, namely the yellowness of gold. In the second statement, "There was an earthquake in Skopje in 1963", the fact is pointed towards by the overall coherence of a set of irreversibly modified properties of objects, each one being considered as an indirect sign of the fact. It is however possible to attenuate this latter semantical intricacy.

Obviously, we shall not reach this aim by just *identifying* the second type of objective fact (transient events) with a certain set of irreversibly modified properties of objects, or even with its overall coherence. True, this kind of definition would carry with it an

[5] Eyewitnesses can be referred to in a third-person way, and be thereby equivalent to spatio-temporal continuants bearing traces of events in their brain. They can also be taken, according to the simulation theory, as conveying a sense of present evidence grounded in memory.

important simplification, for the first type of objective fact would just appear as a special case of the second one (a single property can be construed as a one-membered set of properties, and it is obviously coherent with itself). But it is perfectly conceivable, however unlikely, that a given event has left no trace and/or that *I* am the only eyewitness. Nothing in the grammar of the word "event" precludes speaking about an event which in practice left no traces and had only one eyewitness or even none at all. It thus seems that the distinction between the event and the set of properties of objects which point towards it is inescapable. A distinction nevertheless does not mean the absence of any hierarchical dependence. Even from a realist viewpoint, one must admit that if *any* talk about permanent properties of spatio-temporal continuants were *in principle* precluded, there would remain no ground for referring to past *transient objective facts* (events) at all.

To recapitulate, reference to objective facts ultimately relies on the *possibility* of speaking meaningfully about properties of spatio-temporal continuants. Answering the question as to whether there *are* objective facts in quantum mechanics therefore requires careful scrutiny of another question: can we speak unproblematically of properties of spatio-temporal continuants in quantum mechanics? But the answer to the latter question is essentially *"no"*. The attempt at organizing the quantum world as a plurality of spatio-temporal continuants with which one can associate permanent properties raises formidable difficulties.

To begin with, the concept of its properties raises serious doubts. For instance, it is well known [d'Espagnat B. (1975; 1984)] that (some equivalent of) the concept of underlying properties of objects is an essential ingredient for the demonstration of Bell's inequalities, and that these inequalities in turn contradict certain predictions of quantum mechanics. It is also well known from the Kochen-Specker theorems that most micro-properties are *contextual* and that they are therefore closer to the concept of "relational attribute" than to the ordinary concept of "property". But one can also give a more direct argument,

bearing on the possibility to consider the very values of the quantum observables as properties.

What is a property? A property is, etymologically speaking, something which is proper to an object; namely something which, within certain boundaries, does not depend on external contingent circumstances. In everyday life, there are two major criteria enabling one to decide whether or not it is meaningful to say that a phenomenal fact reflects some property of an object. The first criterion can be called "necessity". "Necessity" means the following: whenever certain (phenomenal) conditions are met, a given phenomenal fact obtains (for instance, whenever I see a three-dimensional body, lifting it involves a certain effort: I then say that *weight* is a property of the body). We already know that this criterion is generally[6] not fulfilled in quantum mechanics. The second criterion can be called "reproducibility". "Reproducibility" means that, whenever a given phenomenal fact has been obtained once under given spatial, sensory, or experimental conditions involving a given object, then the same phenomenal fact will obtain again and again for any subsequent occurrence of the same conditions, involving the same object. It will obtain irrespective of the sequence of other observations or experiments which are performed on the object during the interval which separates the two occurences of the same conditions. "Reproducibility" is clearly a weaker criterion than "necessity", for whenever "necessity" is fulfilled, "reproducibility" is also fulfilled, whereas the converse is not true. At any rate, it is the stability, the repeatability, the reasonable independence from contingent circumstances ensured by the two previous criteria, which gives the concept of property its firmer phenomenal ground. Abstracting our discourse about properties from the observational context, and leaving this context fall into oblivion, is a crucial prerequisite for this discourse to make sense. *Alterations* of properties are not precluded, but only as

[6] There are some cases when quantum mechanics predicts an event with probability 1, but this is obviously not the paradigmatic situation.

long as these alterations can be traced back to some historically well-defined altering event ascertained through the testimony of other stable properties.

Unfortunately, the condition of reproducibility is generally not fulfilled by quantum mechanics either (an exception being provided by the observables which obey a superselection rule, such as the electric charge).

Think for instance of a sequence of measurements of two components (the x and the z components) of the spin of an electron. The electron is so prepared that its initial state vector is $|+_z\rangle$. This being done, an apparatus with a recorder whose initial (virgin) state is $|\phi\rangle$ measures successively the x-component and the z-component. The final state of the system is:

$$\frac{1}{2}\,[|+_z\rangle|\phi+_x+_z\rangle+|-_z\rangle|\phi+_x-_z\rangle+|+_z\rangle|\phi-_x+_z\rangle-|-_z\rangle|\phi-_x-_z\rangle]$$

Now, let us ask about what would happen if a further measurement of the x-component of spin were performed. The eigenstates $|+_z\rangle$ and $|-_z\rangle$ write, respectively, $\frac{1}{\sqrt{2}}(|+_x\rangle+|-_x\rangle)$ and $\frac{1}{\sqrt{2}}(|+_x\rangle-|-_x\rangle)$. Then, in the final state after this further measurement, there will be terms in which the recorder has successively registered $+_x$ and $-_x$, or $-_x$ and $+_x$:

$$|\phi+_x+_z-_x\rangle,\ |\phi+_x-_z-_x\rangle,\ |\phi-_x+_z+_x\rangle,\ |\phi-_x-_z+_x\rangle$$

A popular way of avoiding the difficulty involves an *altering* event. This is after all the usual strategy for rescuing the notion of property in classical physics and in everyday life. Something like: "the electron actually *possessed the property* of having a well-defined x-component of the spin, but the intermediate z-component

measurement brought about a random *disturbance* which was strong enough to change the value of the x-component". I will not develop here a full set of arguments against this conception [see e.g. Brown H. & Redhead M. (1981)], but let me notice that the invoked "disturbance" has no counterpart whatsoever within the theory. Quantum mechanics *tacitly incorporates* the so-called "disturbance", if any, within its predictions. Trying to make the "disturbance" explicit, or to disentangle it from the formalism, would yield either a hopeless semi-classical infinite regress, or a radical change of theory.

Thus, there is generally no "reproducibility" either within quantum mechanics. What can we gather from that? Even if we do not just *identify* each particular property with a reproducible series of phenomenal facts, we would have no reason to speak of properties in general if there were *in principle* no possibility of rooting them in the phenomenal criteria of "necessity" or at least "reproducibility". More specifically, we would not speak of properties within a given theoretical paradigm, if the theory did not incorporate the specification of reproducibility. Hence, there is no systematic ground in quantum mechanics on which to base a discourse about "properties" of objects. Calling "property" a projector on an eigendirection of some appropriate Hilbert space has become a widespread convention in textbooks, but this is just one of the many moves by which the radical novelty of quantum physics is diluted by language.

The result of our investigation would also be negative if we turned towards the concept of objects as spatio-temporal continuants, rather than focusing our attention on their properties. As Schrödinger noticed long ago [Schrödinger E. (1951)], any criterion of spatio-temporal re-identification is lacking *in principle* in the quantum situation, even if some practical recipes can be given in some (physically interesting) circumstances. He also showed that the quantum version of statistical thermodynamics can be developed entirely by counting (and referring to) individual entities, provided one realizes that these entities are definitely *not corpuscular spatio-temporal continuants* but only eigenstates

which have no spatio-temporal location whatsoever [Schrödinger E. (1952)].

So, *within the paradigm of pure unitary quantum mechanics,* we have no general concept of property, no spatio-temporally continuant objects left, no "exhibit" to show, and consequently no ground on which to base any discourse about objective facts. Hence a slightly reformulated version of d'Espagnat's sentence: "there are no *objective* facts in standard quantum mechanics".

C) Pragmatic facts

Quantum mechanics may lack the possibility of speaking about 'objective facts' as we have defined them, it may mostly lack the concepts of spatio-temporal continuants and their properties on which intersubjective communication can be based, but it is well-known that *its very structure ensures intersubjective agreement*. Let us review rapidly the way quantum mechanics incorporates this agreement.

As we noticed previously, the probabilistic information quantum mechanics provides about a *joint* phenomenal fact (concerning a first-order experiment and a second-order experiment bearing on the recorder used for the first-order experiment) takes the final form:

$$c_1|\,1\rangle|\,\phi_1\rangle + c_0|\,0\rangle|\,\phi_0\rangle$$

Now, the same type of state vector can be written for any number of higher-order experiments bearing on observers:

$$c_1|\,1\rangle|\,\phi_1\rangle|\,0_{1,1}\rangle|\,0_{2,1}\rangle|\,0_{3,1}\rangle\ldots + c_0|\,0\rangle|\,\phi_0\rangle|\,0_{1,0}\rangle|\,0_{2,0}\rangle|\,0_{3,0}\rangle\ldots$$

According to the analysis of section A (and in good agreement with Everett's relative state interpretation, or Rovelli's relational interpretation), this expression basically yields conditional statements about phenomenal facts. For instance: "If I am *now* checking the result of the last-order experiment (say the one bearing on the brain of the n-th order observer), and if I *have seen* that the pointer of the apparatus

was directed towards the digit 0, and that 0 *was* printed on the recorder, and that the memory of every observer from 1 to n-1 contained the digit 0, then I *am seeing* that the n-th's observer's memory contains the digit 0".

We must therefore notice that in the quantum account, the intersubjective agreement *at least* retains the status of a phenomenal fact. But this status is itself quite problematic. The excessive emphasis on first-person statements seems to bring us back to a solipsistic and asymmetric account of intersubjectivity. It looks exactly as if "I" were standing on one side, whereas on the other side the observers 0_1, 0_2, 0_3,...were just *referred to* in a statement of what appears to "me", being thus ascribed the status of third-person entities. However, one should notice that what is privileged in the phenomenal account is not "me" as an overall person, but only "what-is-appearing-(to-me)-now". The actual cut then does not take place between "me" and "the others", but between the pure appearance itself and that towards which it is intentionally directed (between the "content" and the "object" in Twardowski's or Meinong's vocabulary [see e.g. Findlay J.N. (1933)]). The latter type of duality is exactly what Everett managed to display when he introduced "memory brackets" in his notations. If, according to his specifications, we make the slight modification which consists in replacing the writing $|\, 0_{1,x}\rangle$ with $|\, 0_1[...X]\rangle$, we leave room for talk about "appearance of phenomena" besides talk concerning that which the appearance is an appearance of. Let us see how this shift arises.

On the one hand, *any* observer 0_1 is to be considered as a *physical system* (or object) referred to in a third-person mode and about which we have probabilistic information is described by a state vector. Along with this view, the observer's state vector may also describes her *correlations* to other observers taken as objects. In this case, the bracket is aimed at reflecting the correlation, e.g. $|\, 0_1[...X, 0_2[...X], 0_3[...X],...]\rangle$.

But on the other hand the *content* of the bracket appended to *any* observer's state vector must be "capable of the interpretation 'The observer has experienced the succession of events ...X...'" [Everett H.

(1973)]. Accordingly, *each* observer retains a double grammatical status: on the one hand, she is described and referred to as a third-person entity, whereas on the other hand she is just as able to experience appearances as "I" am myself.

Focusing attention on the latter status points towards a generalized situation of interlocution whose main characteristics are reciprocity of intentions as well as equivalence of roles or viewpoints [J. Searle (1969), p. 49], and whose privileged instrument is the *second person of verbs*. Recognizing that an observer is "another myself" who can have experiences as "I" do is to realize that she could hold the position of "you" during a conversation. Studying this kind of reciprocity of experiences, and more specifically of intentions and beliefs, in the context of interlocution, is the aim of *pragmatics*.

In this sense, one could thus say that the quantum account of facts is at most a *pragmatic* one, or that it just deals with *pragmatic facts:* quantum mechanics admits of facts which are recognized intersubjectively, in the context of interlocution.

3. METAPHYSICAL CHOICE

To solve the previous puzzle, there are three available possibilities and three closely associated metaphysical options. Each one amounts to putting emphasis on one of the three varieties of facts we have described. The first attitude aims at recovering at any cost (namely at the cost of denying quantum mechanics the full right to become a universal paradigm of thought) a situation wherein the concept of "objective fact" can legitimately operate. The second possibility consists in trying to make sense of the concept of phenomenal fact and to provide it with some autonomy, since the latter is the minimal reflective nucleus of the general concept of fact, the one which no theory can preclude. The challenge in this case is to account for intersubjective agreement and objects in purely phenomenal terms. Finally, the third possibility consists in developing the pragmatic account for its own

sake. Here, intersubjectivity is obviously no problem, but the status of the concept of object is unclear, and this is therefore the main question which must be addressed.

A) In quest of objective facts

There exist two ways of recovering a situation in which the concept of objective fact makes sense, and both of them have already been quite thoroughly explored. *First way:* looking for a sub-quantum level wherein the concepts of properties, spatio-temporal continuants and objective facts retain their traditional meaning. This amounts either to rejecting completely the validity of quantum mechanics by looking for a different theory, or to supplementing it with additional theoretical elements elements (hidden variables[7]). *Second way:* denying the *universal* applicability of quantum mechanics. To back up this denial, one may notice for instance that the condition of "reproducibility" is essentially fulfilled for bodies of macroscopic dimensions, and conclude that this is a good reason to avoid giving a quantum description of them. One can even root the previous remark within quantum mechanics by demonstrating that, according to this theory, the condition of reproducibility is *approximately* fulfilled for the medium-sized objects of everyday life (the minimal aim of Decoherence theories is just to show this). By denying thus the universality of quantum mechanics, one drives back the philosophical puzzle of the objectivity and communicability of facts, and confines it to the microscopic, atomic, and subatomic, domain.

Bohr's case is quite fascinating in this respect, because even though his final position was essentially similar to the one I have just mentioned, his thought process was much more subtle. He did not start

[7] See Mermin N.D. [1993] for a classical review of the extremely stringent conditions a hidden variable theory must fulfill in order to recover the quantum predictions. See also A. Leggett [2003], and Gröblacher et al. [2007] for recent advances.

his reasoning with the approximate applicability of the concepts of property and objective fact at the macroscopic level. He rather set down a very strong requirement of unambiguous intersubjective communication, and then derived from this the *methodological* necessity of a cut between a domain ruled by quantum mechanics and a domain wherein the concepts of properties and objective events still make sense. The latter domain was to be ruled by classical mechanics. We shall see later on (in section 3-C) that the linguistic premise of Bohr's reasoning can be considered as an anticipation of the pragmatic approach to facts. However, Bohr did not fully develop this approach because his tendency was to give a semantic reductionist account of pragmatics.

B) Transcendental phenomenology

The previous attempts at recovering a workable concept of objective fact actually rely on rejection of the validity or universal applicability of the quantum theoretical paradigm rather than on a proper "interpretation" of quantum mechanics. If we feel dissatisfied with the latter option, and if we wish to work out the quantum paradigm towards its ultimate consequences, we must try to give a coherent account of physical knowledge which does altogether without the concept of objective fact. In this section, we shall focus our attention on the possibility of drawing a satisfactory picture if the only concept of fact one retains is that of *phenomenal fact*, and if the whole account is given self-consistently and exclusively in terms of appearances.

Our first task is to get more completely rid of the charge of solipsism than ever before. True, a phenomenal fact (namely an abstract content of phenomenal experience) can but be stated by using the first-person pronoun "I", and spatio-temporal indexicals such as "now". Moreover, the usual token-reflective definitions of "I" and "now", according to which "I" refers to the person who speaks and "now" refers to the time of the utterance (or more realistically to a short

duration following this utterance), immediately suggest that the phenomenal fact just belongs to a particular person at a particular time. In this case, an account in terms of phenomenal facts looks "egocentric" in the strictest sense. But these definitions of "I" and "now" are definitely incompatible with the very option of giving a completely self-consistent account in terms of phenomenal facts. Indeed, the token-reflective definitions of "I" and "now" are typical third-person statements referring to objective entities. The definition of "I" refers to "a person" which, according to Strawson (1959), must be construed as an objective entity to which psychological as well as physical predicates can be ascribed. Similarly, the definition of "now" refers to an *event* (the utterance of the very sentence which contains the word "now"), and therefore to an objective fact. If the definitions of "I" and "now" were given in terms which completely suit the phenomenal viewpoint; if, in other (provocative) words, a *first-person* account of sentences using the *first-person* pronoun were provided, the situation would be very different. "Egocentrism" would lose its negative connotations, as a side-effect of the disappearance of any *third-person* reference to an objectified "center". That this is possible, and that this may even cast some light on some important aspects of the interpretation of quantum mechanics, will be shown below.

Let us begin with "now". We have already noticed that there is a discrepancy between our experiencing well-defined phenomenal facts, such as "I am seeing that the pointer of my apparatus is directed towards the digit 1, and not towards 0", and the quantum account, which only provides a set of conditional statements. The traditional solution to this dilemma, given by people who believe that quantum mechanics must ultimately *describe objective facts*, consists in contending that there is a transition from a set of *potential* facts (described by a set of conditional statements), to *the actual* objective fact. This conception raises a lot of well known difficulties. But I want to concentrate upon *one* of them.

Remember: even if it is not *identical* to the concept of permanent properties of objects, the concept of objective fact at least *relies on* the possibility of circumscribing a coherent set of permanent properties of objects (for instance measurements apparatuses, recorders, eyewitnesses etc.) which all point towards a *past* event. It is an essential feature of an objective fact that it refers to the past, for it relies on the possibility of defining a set of traces. The word " fact " itself testifies in favour of this interpretation, since it comes from the latin "factum" which is a perfect form of the verb "facere". Thus, if we are to make sense of the idea of transition from potential facts to the actual objective fact, this transition *must, by definition,* have occurred at a certain moment of time, past with respect to any phenomenal awareness of it. But pure unitary quantum mechanics has nothing to say about this crucial moment of transition from the possible to the actual. It does not even give a set of conditional statements about the time of occurrence of the transition; it does not even say that this time is poorly determined: it says *nothing at all* [Deutsch (1985)]. One can of course decide to use non-quantum criteria to assess this time, but the criteria, and the assessment as well, can then but be arbitrary. Even the very cautious statement according to which actualisation of an objective fact must occur within the time interval which separates the beginning of the object-apparatus interaction and the present awarenesses of the result, finds no justification whatsoever within pure unitary quantum mechanics.

Let us consider at this point what happens if one renounces the notion of objective fact and relies exclusively on phenomenal facts. If we still wish to speak in terms of actualisation, and if we are asked the question: "when does the (phenomenal) actualisation occur?", the answer must take into account the temporal characteristics of the phenomenal fact, be it the immediate awareness of the experimental outcome, or the immediate awareness of having witnessed the experimental outcome. As we noticed previously, the only temporal indication we can give about a phenomenal fact is that it is occurring *now*. But of course, if we accept inconsistently the third-person account

of "now", we are led to a new variety of the impossibility of ascribing a time location to actualisation. It is no more likely that actualisation occurs during the utterance of the word "now" by "me" than at any other time.

But giving a proper phenomenological account of "now" which would relieve us from the difficulty of ascribing a *time* to actualisation, is not so difficult after all. To do this, we just have to point towards the perennial atemporal connotations of the word "now". Let us think about some very commonplace situations. If you try to capture *now,* by shouting: "now, it is ... eight o'clock", it's too late; eight o'clock is already past. You can also say: "when I shall shout 'eight' it will be eight O'clock", but then your statement does not bear on *now;* it bears on a future instant. "Now" in its most specific sense is temporally elusive, as most continental philosophers from Hegel to Derrida have recognized, and as has been known at least since the epoch of Parmenides. Let me quote for instance a very lucid sentence of the Pseudo-Archytas, a greek philosopher of the first century: "The now, being indivisible, is already in the past while being spoken of, and apprehended"[8].

This being recognized, the puzzle of actualisation can find a quick solution. On the one hand, as previously mentioned, we cannot say that the actualisation of a particular experimental outcome has *never* occurred, for *I am just seeing that the pointer of my apparatus is directed towards the digit 1 (or I am just remembering this)*. But on the other hand, nothing in the formalism of quantum mechanics allows us to contend that actualisation occurred at a certain time. Nothing allows us to say so, except by the conventional act of state vector reduction, or by wrongly equating the true actualization of *one particular outcome* and decoherence.

If we renounce the concept of objective fact, the concept of event, and the third-person definition of "now" (with its connotations of "spurious present"), then we can remove the apparent contradiction

[8] Quoted by Simplicius, Cat. 352-24, in: Sambursky [1971] p. 25

and make perfect sense of the previous remarks. Indeed, in this case, we can both contend that:

(i) It is true that actualisation does not occur in time

(ii) It is not true that actualisation never occurs

The two above sentences are made compatible by two further remarks:

(i) Actualisation occurs *now*

(ii) Now is not a time, but nor is it *never*. (There is an intentional analogy with Wittgenstein's remark: " (A sensation) is not a *something*, but not a *nothing* either! " [Wittgenstein (1983)] §304))

In other terms, when actualisation is *not* taken to be synonymous with "objectification" (namely of transition from potential facts to an actual *objective* fact), the puzzle of "occurrence without a time of occurrence" is defused.

These ideas are not completely unheard in contemporaneous work concerning the interpretation of quantum mechanics, but they are often formulated in a confusing way. For instance Wheeler, in his celebrated paper "Law without law" [Wheeler J.A. (1983)], tells us that "Registering equipment operating in the *here and now* has an undeniable part in bringing about that which appears to have happened". This allows him to account for the putative action of the present on the past, in delayed-choice experiments. But Wheeler's vocabulary is misleading. When his arguments are carefully scrutinized, we see that what he speaks about is not just (as we did) present perspective on the past, but action of an act of irreversible recording on the events which are past *with respect to it*.

The transactional interpretation of quantum mechanics, which was stated by J.G. Cramer in 1986, comes even closer to the idea that actualisation occurs *now*. Cramer's basic idea is that any quantum event results from a time-symmetric transaction between the emitter of a wave Ψ, and a potential future absorber. The emitter sends an *offer* retarded wave Ψ, and the potential absorber sends back a *confirmation* advanced wave Ψ^*. But at this point, something new happens: "The

boundary conditions will permit only one event to occur" [Cramer J.G. (1986)]. Paraphrasing Wheeler according to whom *no phenomenon is a phenomenon until it is a recorded phenomenon,* Cramer claims that *no offer is really a transaction until it is a confirmed transaction*. And he then shows that this confirmation occurs with the probability $\Psi\Psi^*$. Thus, among the possible transactions taking place between an emitter and several (possibly an infinite number of) potential future absorbers, only *one* is completed. This completion plays the role of the actualisation in the orthodox account. However, there is a major difference between confirmation of a transaction and orthodox actualisation. Cramer tries to document this difference, but I think he fails to make it clear. Orthodox actualisation occurs somewhere within the measurement chain, and at some instant between the interaction and the completion of the recording. Confirmation of a transaction also *occurs*, but it occurs "atemporally and non-locally across any sort of interval between elements of the measuring apparatus". At least it could seem that the occurrence of the confirmation of the transaction is bounded by the volume of the apparatus and its life-span. But things are not so simple. An analysis of the cat paradox leads Cramer to remove any spatio-temporal boundary:

> The event is finished when the transaction forms, which happens along a set of world lines that includes all of the events listed above, treating none of them as the special conclusion of the event.

The "events listed above" referred to by Cramers are all the events of an indefinitely developing measurement chain, possibly including open-ended cerebral processes. Cramers eventually adds a crucial remark:

> *The atemporal transaction does not have a "when" at its end.*

If Cramers had realized that the most specific sense of the word "now" is precisely characterized by the absence of answer to the

question *when* is *now?,* he would certainly have said that the completion of a transaction occurs *now*, "contemporaneously" with the phenomenal fact which is testifying it. But then, his pictures of waves, emitters and absorbers would have appeared to him as irrelevant metaphors. Indeed, in the Wheeler-Feynman theory of electromagnetism, which inspired Cramers, absorption and emission are two spatio-temporally well-defined events, whereas this is not so, at least for absorption, in the transactional interpretation of quantum mechanics.

Let us proceed with "I", and further discuss the consequences of reverting from a third-person view to a self-consistent phenomenological view of this pronoun[9]. A third-person account of "I" (which then reduces to " me ") would naturally lead to equating a phenomenal fact expressed in a first-person mode with a "subjective fact". But what is it that makes a fact "subjective"? Saying of a fact that it is "subjective" amounts to ascribing it to a fraction of the world: this human being rather than other human beings, or the so-called "internal realm" rather than external reality. In other words, when you say that an event is "subjective", you implicitly mean that this event is embodied in a property of a particular entity in the world, be it a particular human body, or some psychical entity such as "consciousness" or "mind". When you say that an event is " subjective ", what you are actually trying to do is to project onto it the *model* of the objective fact while restricting this fact to some special objective entities such as human bodies and minds. This is not to assert that any use of a psychological language binds you to the position that subjective events are ultimately *identical* with a special class of objective facts. But at the very least, the concept of a subjective fact retains two typical features of objective facts: 1) ascription of a *time* to it, namely correlation with a property of an object called a clock and 2) correspondence with a *property* of an entity in the world (possibly a mental one). In contrast with, e.g., Eugen

[9] For approaches of the measurement problem along these lines, see S. French [2002], and M. Bitbol [2000, 2008]

Wigner's contention [Wigner E. (1967)], it thus becomes clear that the introduction of a "subjective" ingredient helps in no way to solve the measurement problem of quantum mechanics. For actualisation construed as a subjective fact (i.e. as a mental event occurring in a subject) would have to be ascribed two characteristics which are not consistent with the quantum account.

But a proper first-person account of phenomenal facts leads to diametrically opposite conclusions. According to such an account, a phenomenal fact has just the two negative features which makes it safe from the quantum puzzles:

1) it does not have a time of occurrence (for it occurs "now")

2) it is not to be ascribed to any third-person entity (be it a person or a mind). Indeed, there is only one sense in which it would remain acceptable to say that phenomenal facts pertain to some subject: it is to say that they pertain to *the* (transcendental) subject. *A* particular subject is commonly defined as an entity which can be referred to, and to which conscious or unconscious psychical contents are ascribed. But in another sense (pinpointed by using the definite article "the") the word "subject" points towards the *referring* background of any entity *referred to*, be it a psychical content or a person. The latter definition arises from a very old idea: that of the atemporal *knowing subject,* which was featured in a short and enlightening way by K. Dunlap: "Knowing there certainly is; known the knowing certainly is not"[10]. It is also reminiscent of the "transcendental Ego" as opposed to the empirical or psychological ego, in the line of Husserlian phenomenology. As I noted previously, this viewpoint has nothing to do with the most absurd form of solipsism which attributes a privileged status to a given person *in* the world. Here, the privilege, if any, is conferred to the "subject *for* which this world has being" [Husserl E. (1931) p. 14].

[10] Quoted by B. Russell [1978], p. 115; see also Natorp's concept of the "pure ego", quoted and discussed by E. Husserl [1913].

But have we not been led to a kind of self-referential and self-ignorant form of solipsism? Have we not just concealed the priviledge of "my" position by giving a circular first-person account of sentences beginning with the first-person pronoun? That this is not so can be gathered from the core of Husserl's account of intersubjectivity: "the fellow subjects (...) reveal themselves as *co-transcendental"* [Husserl E. (1931)][11]. One cannot thus say that, in phenomenology, the existence of other "subjects" is inferred secondarily from the data available to *a particular* transcendental Ego. These other subjects are rather direct and immediate constituents of *the* transcendental field within which the world is posited. They partake of the condition of possibility of a world constituted transcendentally as "being there for every one".

Now, this idea of "co-transcendentality" is in perfect agreement with what arises implicitly in quantum mechanics from the writing of higher-order Everett memory brackets (which, as we already mentioned, by no means represent quantum states but associated *phenomenal contents)*. Let us consider for instance the bracket:

$$[..X,\ 0_2[..X,0_1[..X..],0_3[..X..]...],\ 0_3[..X,0_1[..X..],0_2[..X..]..],..].$$

True, the mere absence of 0_1 in the first level of bracketing is enough to see that its content pertains to a particular viewpoint. However, the perfect equivalence, reciprocity and agreement of appearances, is displayed through the hierarchy of brackets *within* the first-level brackets. Co-transcendentality is already operational at the level of *each* transcendental field, be it particularized by a certain hierarchical ordering of phenomenal contents which can metaphorically be called a *"viewpoint"*, or a *"monad"*.

[11]Husserl also wrote a more extensive defence against solipsism in the fith meditation of His *Cartesian meditations,* but the clarity and conciseness of the argument in his introduction to the English edition of the *Ideen* is much higher.

This equivalence of appearances from any viewpoint would arise even more directly from a pragmatic account than from the co-transcendantal one. But before coming to pragmatics, we must address (very shortly, with no pretention to completeness), the problem of the status of objects in a phenomenological-transcendental philosophy. The problem is the following: objects and objective facts are usually referred to in the very description of the abstract contents of experience which consitute the phenomenal facts. Then, in order to maintain the self-consistency and self-containment of the phenomenal account, one has to account for this reference to objects *without relying in any respect on a naive realist picture*. The most radical move would consist in showing:

(i) that it is possible to do without any talk of objects, by using a pure "observational language", and

(ii) that talk about objects can however be justified as an economical means of description, through a constructivist procedure.

Since the time of logical empiricism, this attempt has nevertheless shown its limits [Carnap R. (1967); Sellars W. (1963)]. A more cautious account was given by Husserl who did not try to eliminate objects from the phenomenological scenery, but rather to develop a thorough "eidetic" *description* of "things" as experienced. The end result of the analysis, namely that things are to be considered as intentional meaning-products of transcendental subjectivity, does not arise from some initial *tabula rasa* leaving only pure sense-data, but rather from a mere "readjustment of viewpoint" called "phenomenological reduction". Husserl thus at the same time aknowledged the legitimacy of talk about objects and noticed that, in so far as they are just objects *for* the (co)-transcendental subject, their existence is only *relative*. As a consequence, their *non-existence* remains thinkable. The quite peculiar situation of present-day physics, wherein talk about objects and objective facts is very widespread in spite of its being *in principle* foreign to the current theoretical paradigm, can thus easily be accommodated in a phenomenological outlook. Speech about objects can be warranted in the description of an experiment and of its end result, even though their

existence is not paradigmatically (or otherwise) guaranteed. Such circumstances are even easier to tackle by following the pragmatic line of thought, as we shall see below.

C) Practical reason and Pragmatics

Even if one is convinced that the phenomenological (first-person) approach is, broadly speaking, able to afford a consistent account of appearance, the resulting picture may still be felt to be unsatisfactory in some respects. Let us then go a little deeper into the matter.

One of the conceivable departure points of phenomenological thought consists in working out systematically the consequences of the *double incompleteness* of knowledge. What I mean by "double incompleteness" can best be grasped from an elementary insight into the grammar of the word "knowledge". In some contexts, one speaks of knowledge *of* (something) whereas in some different contexts one may speak of knowledge *for* (somebody). In other terms, the word "knowledge" implies both *intentionality* and *reflectivity*. This has two symmetric consequences.

Firstly, if we call "object" that *of which* there is (or there might be) knowledge, then this may mean that objects themselves are only given *relatively,* that they are *defined* as objects of knowledge *for*.... But at this point, overcautiousness is crucial. We must avoid the simplification we made in the first opposition we stated between knowledge *of*... and knowledge *for...,* when we filled the dots after "for" by "(somebody)". We must temporarily keep the dots after "for" empty, since none of the words which usually fill the gap would enable the concept of object to encompass its full range. For instance, saying that an object is an object for the *intellect* would restrict it to be an object of thought; saying that an object is an object for *imagination* would make it a fictitious object; saying that an object is an object for *the senses* would make it a purely sensible object; trying to make a synthesis of the previous

characterizations by saying that an object is object for *somebody* (as we tentatively did) would make it *subjective*.

Secondly, if we insist on the idea that any knowledge has an object, that it is knowledge *of*... we are confronted with the circumstance that the overall field of *actual* appearance can be experienced but not *known* or investigated. For as soon as appearance is taken as an object of (possibly introspective) investigation, this is done at the cost of its being no more actual or self-coincident [Merleau-Ponty M. (1945), p. 388].

The characteristic move of phenomenology then looks like an attempt at bypassing this double incompleteness, and at providing knowledge with new kinds of foundations. In phenomenology, the objects do not remain just objects-for... with final dots; they become objects for *the transcendental subject,* the latter being characterized by saying that it is neither a man, nor a person (somebody), nor any kind of mental entity; if it is to be something, then it is essentially ...*for whom any object can possibly be an object,* with initial dots. Similarly, rather than merely saying that the actual appearance is definitely out of reach of knowledge and pushing it aside with the status of Wittgenstein's "limit of the world"[12], Husserl tried to circumscribe it as "self-exhibiting", "self-giving", "immediately intuited" [Husserl E. (1960) p. 57], or as identical with the *living-present* which concentrates in itself all the previously mentioned elusive features of "now". In that respect, phenomenology clearly appears to be a late product of a long tradition nowadays called (especially by J. Derrida) "the metaphysics of presence", and that we could as well call "completion by immediacy". Immediacy of experience here plays the foundational role which is denied to " things in themselves " or " external reality ".

What is to be done at this point if one wishes both to avoid mere ignorance of the problem of incompleteness of knowledge, and yet to do without any explicit or implicit foundationalism? I can see two possibilities, the one being closer to ignorance, and the other closer to

[12] L. Wittgenstein L. (1961) 5.632, 5.641

the foundationalist aim. The first possibility amounts to seeking something like an *objective substitute* for every item which is missing in knowledge. In this case, human beings or brains usually hold the role of the missing subject, whereas objective facts hold the role of the elusive immediate appearance. However, this approach is close to ignorance (of the problem of incompleteness of knowledge). The substitutes for the missing subject are still relative objects-for..., which means that the question " for whom? " has only been pushed one step further. Similarly, even though objective facts can appear to every one, they are still objects of knowledge and as such definitely distinct from the appearance itself.

So, let us turn to the second possibility. It consists in accepting a kind of systematic duplication of the way we look at the world: the world as object of knowledge and the world as the medium of action, the world as grasped by theoretical reason and the world as moulded by practical reason, the world from the point of view of the spectators and the world from the point of view of the actors [Beck L.W. (1960)]. Duplication here does not imply any duality of the fields of application of theoretical and practical reason; it does not carry with it any idea of borders. Rather, each mode of approach tends to encompass the whole field, and to give an account of the other in its own terms. The practical attitude consists in giving any object the status of a tool for action, whereas the theoretical attitude ultimately aims at describing any action as a set of objective events concerning a (human or animal) body and its environment.

Therefore, reference to the practical approach besides the theoretical approach is not meant to afford a way to *complete* theoretical knowledge; it is not meant to circumscribe a domain of operation for the missing subject within the whole field of knowledge. It is rather meant to *make manifest* the impossibility of performing the completion. Indeed, the structural features of action point *reflectively* towards its missing source [Ricoeur P. (1990) p. 48, 55] and, therefore, the persistent necessity of giving a practical account of action displays as

clearly as possible the very *fact* of incompleteness. If, conversely, any knowing-how could be turned into proper knowledge [Anscombe G.E.M. (1979)], if intentions, meanings, motivations could have their source identified in a third-person mode while being experienced, if in a word theoretical knowledge could be *completed,* the practical approach would be superfluous, and the theory/practice duplication would just mean redundancy.

An important case of the above distinction arises in linguistics, where it takes the form of the pair semantics/pragmatics. Here again, the two disciplines do not rule separate domains: they rather operate as incompatible approaches to the overall field of semiotics, and they tend to absorb each other.

First, absorption of pragmatics by semantics. Semantics is supposed to focus attention on a relation between the parts of language and what they designate or refer to, namely objects or events. Pragmatic speech about intention, belief, presuppositions, and context of use, is therefore not only beyond its scope: it calls for reduction. The tentative reduction in turn takes two forms.

One of these is the semantic side of the general trend towards absorption of practical reason by theoretical reason. As soon as one aknowledges that speech about actors, acts, and purpose, can in some way be reduced to a particular mode of studying objects, events, and causality, pragmatics loses any specificity. It merges into a general theory of objects and their relations, of which semantics may be construed as a branch in so far as it establishes a relation between certain object-signs (noises or marks on a piece of paper) and their designated objects.

But there is also a more direct version of the absorption of pragmatics by semantics, discussed by R. C. Stalnaker [(1974)]. According to it, presupposition Q is the set of propositions he takes for granted when he states that P. The reductive semantic account of presuppositions thus tends to eliminate the speaker from the picture by focusing attention on the set of propositions {Q,P}: "P presupposes

that Q iff Q must be true in order that P have a truth value at all". However, this account clearly fails to grasp the sublety of the pragmatic concept of presupposition, for it is much too strong and rigid to do the job. A speaker can carry through a certain presupposition Q when he asserts P, even though he has no commitment to the truth of Q. The "presupposition" Q often does not go beyond the status of a useful tool, for the sake of communication with an audience which happens to share it. As Stalnaker rightly pointed out, in everyday dialogues a presupposition is usually much less than assumption of truth, and even less than belief. Just "a disposition to behave in one's use of language *as if* one had certain beliefs". Therefore, pragmatic cannot be entirely reduced to the semantics of propositions Q.

Difficulties in reducing pragmatics to semantics suggest to try reduction in the other direction. The investigation then tends towards absorbtion of semantics into pragmatics, and its major aim is to give a proper account of reference as *speech act*. This direction of thought was followed by Searle [1969; 1971], who consistently considered that, like any other action, reference can either succeed or fail. The ultimate criterion of success is unambiguous *identification*, by the speaker, of the object referred to, and communication of this identification to a hearer [Searle J.R. (1969) p. 82]. However, in most cases of everyday conversation, identification (which requires ostensive acts or descriptions) is not actually achieved. Searle thus makes a distinction between fully consummated reference, wherein the object referred to has actually been identified, and simple successful reference which does not convey any more than a *capacity* for identification.

At this point, a more refined analysis is needed if we are to meet the requirements of the awkward situation of modern physics. Following Searle's definition to its logical conclusion, reference cannot be unambiguously categorized as a success or a failure until one has given an assessment of the crucial *capacity to identify*. We then need to make a further distinction between (i) *practical* capacity to identify and (ii) *paradigmatical* capacity to identify.

(i) Having a *practical* capacity to identify means being able to pick out the object referred to by ostension or by partial descriptions, from among all the other objects which are presupposed in the context of speech.

(ii) Having a *paradigmatical* capacity to identify is quite a different matter. It means that a theoretical paradigm (or a generally accepted view of the world) taken as a presupposition allows one *in principle* to identify a particular object (from among the other objects of the same type) by making use of individualizing descriptions and/or spatio-temporal criteria of identification *having a symbolic counterpart within the theory, and acceptable as a component of this theory*. Reference to a certain particle P is for instance paradigmatically successful in classical mechanics, for within this theory a particle can be individualized *in principle* by its position at a certain time and reidentified along a continuous trajectory.

At first sight, the practical and paradigmatical sources of legitimacy for the speech act of reference are definitely distinct in scope and extent. To begin with, it may happen that an act of reference is paradigmatically successful without being practically successful. Reference to a certain particle P, for instance, is *always* paradigmatically successful in classical mechanics, although no currently available experimental device enables one *in practice* to distinguish P from other particles above some threshold of tight packing. Conversely, the possibility also exists of an act of reference being practically successful without being paradigmatically successful, *at least for a certain paradigm of thought*. One may in practice identify the water of a holy water font by its having undergone the rite of blessing in the past. Yet, there is no counterpart of the general symbolic distinction between holy water and other samples of water in chemistry. Reference to holy water is therefore unsuccessful in the paradigm of chemistry taken in isolation.

However, this apparent symmetry conceals a major difference and a widespread bias in favour of paradigmatic legitimacy. Firstly, paradigmatically successful reference conveys the prospect of its being

associated with practical success as soon as the available means of identification reach a sufficient level of sophistication. Paradigmatic legitimacy can thus be construed as long-range or even infinite-range practical legitimacy. Moreover, one usually considers that as soon as one is able to make a practically successful reference, this means that there exists a theoretical framework, already known or yet to be discovered, whereby the initial success could be converted into paradigmatically warranted success. For instance, practically successful reference to holy water can be converted into paradigmatical success in the framework of some anthropological theory of symbolic acts. If this is true, paradigmatical legitimacy should clearly be granted a much stronger status than its practical counterpart. Its potential ability to encompass every case of practical success, its generality and rigidity, might even well lead one to forget that it has a primarily *pragmatic* origin (through its belonging to the set of pragmatic presuppositions). Paradigmatic success of reference would then be confused with an *unconditional* success depending only on the structure of the language and of the world. It would yield both the temptation of reducing any account of reference to pure semantics, and the correlative prospect of a realist outlook.

I can only see two types of situation wherein the support of realism and semantic reductionism by generalization of paradigmatically successful reference clearly shows its limits. The first one is scientific revolutions, during which, no paradigm being uncritically presupposed, the practical criteria of successful reference gain a renewed (but temporary) support. The operationalist trends of these periods are clear signs of the revival of practical modes of identification. The second situation is one in which, even though a theoretical paradigm has become well accepted, some cases of practically successful reference can only be encompassed within *another* paradigm *incompatible* with the former one. *As we will see in our discussion of Bohr's positions, this is precisely where the quantum puzzle lies.*

Before we discuss the status of practically successful reference in the quantum situation, let us come back to the root of the problem: *incompleteness*. Much was said about the so-called "incompleteness" of quantum mechanics in the early days of the theory. One of the most staightforward versions of the charge of incompleteness was given by Schrödinger in his 1935 "cat paper" [Schrödinger (1935)]: quantum mechanics is incomplete because it does not say that the cat is definitely dead or alive after the well-known cruel experiment has taken place, although *we can perfectly well see* that it is either dead or alive just by looking in the box. But is this kind of incompleteness a unique characteristic of quantum mechanics? If we take the previous statements at face value, they basically assert that quantum mechanics is incomplete because it does not incorporate *the phenomenal certainty of having seen a cat in a definite biological state*. This assertion does not go beyond a mere restatement of the general (self-referential) incompleteness of knowledge and it thus cannot pretend to have picked out any distinctive feature of quantum mechanics. What is then so peculiar about the quantum situation? *It is that, in quantum mechanics, any reference to an objective substitute for phenomenal certainty (or for immediate appearance), namely any reference to an objective fact, is paradigmatically illegitimate*. As we saw previously, the relevance of the indeterministic features of the quantum description on our conception of facts is not that they do not incorporate our present awareness of a single definite phenomenal fact, for this is a perfectly trivial deficiency of theoretical descriptions in general. It is rather that these indeterministic features wipe out the criteria of "necessity" and "reproducibility", without which the concept of *objective fact* can be provided with no ground. In other words, quantum mechanics is just *as incomplete as any other branch of knowledge*, but unlike most other branches of knowledge, it paradigmatically forbids our getting round incompleteness by calling for an objective substitute (or "exhibit") for the missing pure appearance. This ban on objective substitutes for pure appearance can be considered as a flaw in quantum mechanics, but I think it is not to be

regretted, since in the past the concept of objective fact was used as an artificial device serving to conceal a basic feature of knowledge.

The right attitude to be adopted in the quantum situation is then to revert to the second and last way of accommodating the problem of incompleteness of knowledge, namely duplication between the practical and theoretical modes of description, between pragmatics and semantics, and (within the field of pragmatics) between practical and paradigmatic legitimacies of reference. Actually, this duplication has operated more or less implicitly since the very beginnings of quantum mechanics. Let us consider some of its most striking aspects.

The concept of particles as spatio-temporal continuants endowed with properties still retains some credit among physicists (at least if one takes the vocabulary they use at face value), in spite of its having no complete counterpart in the theory. This can be explained as follows. True, reference to a particle is paradigmatically illegitimate, for no criterion of identification (neither form nor spatio-temporal continuity) can work *in principle* according to quantum mechanics. But there are circumstances (great distances or macroscopic scale) wherein one can determine an approximate path which overlaps very slightly with other approximate paths and accordingly obtain a reasonably high probability of successful identification. Therefore, reference to a particle and more generally to spatio-temporal continuants gains practical legitimacy from these circumstances. By pushing this legitimacy to its limits, one feels allowed to talk of particles even when experimental criteria of discrimination lack. Now, it must be stressed that this is not just a marginal way of speaking, or a matter of interpretation. Even the physicists who are most committed to giving a self-consistent interpretation of quantum mechanics still speak as if they thought that the state vector (or wave function) has to be the state *of something*. But of which kind of entity? The most cautious mode of expression involves the concept of "system", the latter being merely defined by a certain set of degrees of freedom. The state vector describes the state of a *system,* full stop. Very few physicists however resist the temptation to going

one step further when they are asked to explain what they mean in everyday language, and to identifying thereby the "system" with *something like a spatio-temporal continuant* (be it an electron, an experimental apparatus, or the universe as a whole) to which the same set of degrees of freedom is associated.

One reason for this persistent background presence of the concept of spatio-temporal continuant in talk about quantum mechanics is that one has to accommodate the success of predictions on repeated experiments, expressed as follows: "If you measure observable A on an electron and then repeat the measurement immediately on the *same electron*, then you will get the same result twice". Taking the previous sentence litterally, it seems that the state vector which enables one to predict reproducibility for a given outcome of the measurement of observable A has to be considered as the state vector *of the electron*, thus lending a kind of indirect paradigmatic support to reference to spatio-temporal continuants. However, this support is only apparent, for it arises from a mixture of practical and paradigmatical legitimacy. Practical legitimacy of reference to electrons *in certain circumstances (low densities, frequent monitoring...),* and paradigmatical legitimacy of reference to state vectors. The practical account in terms of electrons, bodies and any other spatio-temporal continuants is useful when it is employed to describe repeated experiments, but it can be dispensed with, since the paradigm of quantum mechanics is no less apt to give a consistent account in its own terms. Within quantum mechanics strictly speaking, the situation of repeated experiments can be stated by saying that some eigenvalue of an observable A is strongly correlated with given eigenvalues of the observables Mass, Charge and Position (modulo unitary evolution of the latter). No concept of "electron" has ever to arise. In quantum physics as in any other domain of thought, the practical and the theoretical accounts have no priviledged domain of their own; they are separated by no borders; they rather act as two fully developed but incompatible accounts of the same processes. One of the main difficulties of the quantum situation is that

the practical account is so hard to replace in terms of economy of descriptions, that it tends to be forced into the current theoretical framework.

This can be seen even more clearly by following some historical trends in the discussions of the measurement problem in quantum mechanics. Let us come back to Schrödinger's cat. One can give two fully coherent but incompatible accounts of the corresponding process.

(i) The practical account is entirely organized in terms of reference to spatio-temporal continuants, of their properties and of their interactions, and it ends up by stating a fact: "An α-particle has been emitted by a piece of radio-active material, the Geiger counter has been triggered, the hammer has broken the flask of prussic acid and the cat has been killed". The event-like fact "the cat has been killed" is attested by the *practical* legitimacy of reference to permanent properties of the spatio-temporal continuant "cat's body", and it is then (in practice) equivalent to an objective fact.

(ii) By contrast, the theoretical account just refers to state vectors and observables: "A certain overall state vector Ψ° has been submitted to unitary evolution according to a hamiltonian H including cross-linked variables, and it ends up in a configuration Ψ which is *not* an eigenstate of some (very complex) observable Σ". The overall state vector Ψ° is usually defined as "the state vector *of* the whole experimental set-up from the radio-active material to the cat", but it can equally be construed in purely quantum-mechanical terms as the eigenstate of a preparative observable Π°, and as a probabilistic expression of the corresponding preparation. As for the hamiltonian H, it is usually called an "interaction hamiltonian", but it can equally be characterized by the impossibility of separating certain sets of variables within it. One must however recognize that this ascetic attitude, however coherent, is threatened by overcomplication.

It is of course at this point that the well-known paradox arises, but we can now grasp its origin very clearly. The paradox comes from the attempt (or the economical necessity) to project *every* element of the

practical account, including the paradigmatically illegitimate reference to event-like objective facts such as "the cat has been killed" and "the cat has not been killed", into the theoretical account. True, the theoretical description must bear some *relation* to the practical account, if it is to be called a *physical* theory. However, in spite of what the common use of the word "state" in the expression "state of an object" suggests too strongly, this relation does not reduce to a one-one mapping between a certain state vector and the practically construed "state" of a certain object. It is only established indirectly, through a correspondence between (a) the eigenvalues of the observables and the accessible outcomes of measurement, and (b) the squared complex coefficients multiplying each eigenstate and the limit of the frequency of the corresponding outcome.

The history of quantum mechanics exhibits both scattered recognition of the special role of practical elements of speech, and desperate efforts to provide them with some sort of paradigmatic legitimacy. What is at stake here is nothing less than the possibility of giving firm ground to every act of reference, the prospect of reducing pragmatics to semantics, and the recovery of an unproblematic all-encompassing conception of *the* (semantically referred to) objective reality. Bohr's case is very peculiar in that respect, for he was the first one to state completely the premises of a pragmatic conception of facts and to formulate the quantum puzzle in terms of paradigmatic legitimacy. As we noted previously, he constantly insisted on the unsurpassable status of unambiguous communication in the process of acquisition of empirical scientific knowledge. Everyday language, with all its (practically successful) references to spatio-temporal continuants, to permanent properties and to facts ascertained by a coherent set of permanent properties, let alone its "natural ontological" presupposition about the "existence" of objects, was considered by him as the only one which can (at least in principle) afford unambiguous communication. He therefore assumed it to be the only language which could be used to express experimental processes *qua* leading to definite outcomes, even

in the domain ruled by quantum mechanics. However, Bohr did not accept without resistance the idea that the duality between the practical and the theoretical account, between the practical and the paradigmatic legitimacies of the act of reference, was an irreducible feature of the new framework of thought and a way to express the fundamental epistemic incompleteness for which it can afford no substitutes. He rather tried to embed the presuppositions and the practically successful acts of reference which experimental physics requires, into another (non-quantum) theoretical framework. Classical physics was perfectly suited for this, since it was able to provide any promise of identification of (and any reference to) spatio-temporal continuants or objective facts with paradigmatic legitimacy. The problem is that it is impossible to superpose the classical paradigm and the quantum paradigm throughout the description of a single experimental process. Bohr[13] was then forced to introduce the notion of a *cut* within the measurement chain, although he otherwise considered it holistically. Quantum mechanics was permitted to operate within certain boundaries, whereas classical physics had to rule the part of the experimental set-up which was in closer contact with the community of speakers. The quantum side allowed successful (probabilistic) predictions, whereas the classical side endowed the practically successful reference to objective facts with (a certain) paradigmatical legitimacy and with the prospect of semantical reduction. Completion of this program would have required an attempt at defining univocally the border which supposedly separates the quantum realm from the classical realm. Other physicists tried very hard to fix the position of such a border (mainly by considerations of scale, statistics, etc.) but Bohr emphasized instead that it was mostly a matter of descriptive convenience.

The scientific behaviour of this rationnally reconstructed Bohr should start us thinking again. In Bohr's account of a measurement process, the quantum framework can perfectly well encompass almost

[13] See O. Darrigol, (1992), for a historically accurate review.

everything, provided the mode of description of the very last stage, namely the one which is directly seen by the community of experimental physicists, lends paradigmatical support to speech about objective facts. As for the classical framework, it can *also* encompass almost everything, provided the very first stage of the experiment, or any stage wherein the quantum of action cannot be neglected, is described quantum mechanically. This extreme mobility of the boundary between the two modes of theoretical description simulates as closely as possible the perfect parallelism of the practical and the theoretical account of a measurement process that we have outlined.

Coming back to the idea that the classical framework was not introduced because of some intrinsic feature of the measuring apparatus, but only to fit some crucial rules of intersubjective communication, and bringing it together with the quasi-parallelism of the two modes of theoretical description, we are led to think that Bohr was after all much closer from the notion of a systematic practical/theoretical duplication than he ever acknowledged. But as a physicist, Bohr could not pursue the consequences of this attitude to their logical conclusion, for he would then have had to admit that physics is unable to cope with the situation. In particular, the status of classical theories in the description of a measurement process would have had to be reduced to that of an auxiliary of the practical account. One should have considered that classical physics at most operates as a formal device used to tighten up the acts of reference carried out by scientists with practical success, and certainly not as any proper paradigmatic ground for them. In this way, the universal validity of the quantum mode of description would have been aknowledged, in spite of its inability to lend paradigmatic support to the concept of an objective fact.

Further (but indirect) signs that Bohr was extremely close to the idea of a practical/theoretical duplication can be found in the concept of complementarity. His definition of complementary descriptions, namely pairs of accounts which are incompatible but both necessary to

exhaust all the experimental aspects of some preliminary situation, can perfectly characterize the practical/theoretical parallelism. Indeed, every aspect of complementarity reduces to a single pair of incompatible descriptions: the theoretical description in terms of observables, state vectors, and unitary evolution on the one hand, and the practical description in terms of (event-like) objective facts on the other hand.

Firstly, the well known wave-particle complementarity manifested in interference experiments can be expressed in terms of the incompatibility between a description within the (wave-like) theoretical framework and the practically successful reference to some intermediate event of detection. If no such act of reference were performed, one could perfectly well go on with the (wave-like) theoretical description of the whole experiment (as in Everett's relative state interpretation), and just point out that certain amplitudes become vanishingly small when the degrees of freedom associated to an intermediate detector are accounted for (see the decoherence theories). Secondly, the complementarity between causality[14] and spatio-temporal location reduces to the incompatibility between the theoretical *causal deterministic* description in terms of the unitary evolution of a state vector and the practically successful reference to spatio-temporally located singular events which in general *are not deterministically,* but only probabilistically related. Finally, the general complementarity between canonically conjugate variables *A* and *B* (the corresponding non-commuting observables being A and B) basically reflects the incompatibility between a theoretical description of the "system" in terms of some eigenstate $|a_i\rangle$ of A (namely in terms of a linear superposition of eigenstates $|b_j\rangle$ of observable B), and the practically successful reference to the objective fact that a definite value b_j° of variable *B* has been obtained experimentally. This basic incompatibility may be further

[14] As D. Lewis (1986) pointed out, "causality is a naughty word" because it encompasses causation and determinism. In Bohr's sense, the association is legitimate.

refined in order to underline the absence of reproducibility of the objective fact that a certain value a_i of A has been obtained, if an intermediate measurement of B has been performed.

In brief, one can rightly say that Bohr's complementarities are but multiple reflections of Kant's fundamental dichotomy between theoretical and practical reason. Or, if we wish to come closer to the historical development of quantum mechanics, we may stress that Bohr's complementarities are after all but multiple aspects of Schrödinger's fundamental and *unique* dichotomy between the *continuous* theoretical representation (wave mechanics) and the the practically successful reference to *discontinuous* facts [Schrödinger E. (1951)].

4. CLOSING REMARKS

Quantum mechanics gives paradigmatical legitimacy to acts of reference which are directed towards its theoretical entities (e.g. state vectors). Indeed, as Schrödinger noticed, quantum mechanics *in principle* endows state vectors with a criterion of identification (their "form"), whereas it affords *in principle* no such criterion for spatio-temporal continuants. This circumstance provides the realist conception of state vectors with its strongest justification. However, by its lending *no* paradigmatic support to the acts of reference to substitutive objective facts, by the dichotomy it must maintain between its mode of description and the practical deeds of the community of physicists, by the correlative Everettian distinction between state vectors and memory brackets, quantum mechanics reminds us of a basic incompleteness of knowledge which constitutes by itself a challenge for any realist undertaking.

However, quantum mechanics is not to be considered as extravagant in that respect. It would be more accurate to say that classical physics is. Classical physics is this exceptional and historically isolated paradigm which, by its lending support to practically successful reference to objective facts, has hitherto concealed the fundamental

incompleteness of knowledge. That this concealment is from now on impossible, that the situatedness of knowing subjects can no longer be ignored in their knowledge, might be the most significant achievement of the quantum revolution.

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