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ON EPISTEMOLOGICAL MODESTY

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ABSTRACT

I argue for an attitude of epistemological modesty against the claims that physical theories, e.g. quantum mechanics, favor any ontological statements on the nature of reality.

1 Against ontology

Our brains are wired to do many different things, or at least this is what is often asserted. Brains are wired to look for a cause for every event that they register, so the cause-effect relation looks to us like the most fundamental element of reality. Or brains are wired to construct representations of the external world, so we are not apt to question that the external world exists at all. Solipsism, in this sense, is a remarkable achievement of the human mind, because it goes against the nature of the human brain. It seems interesting to go further down this road and to ask what remains of the philosophy of science if we remove the prejudice of believing that *X* ou *Y* are fundamental just because our brains are wired to hold such a belief. Human habits, conventions, natural inclinations and neuronal connections all have to go.

But can they all go? Take the problem of foundations of a physical theory. What remains of a theory if we remove its human users from the picture? Probably not much, or at least if we take one given theory at a time. Quantum mechanics relies on a convention about multiple runs of experiments on identical systems, or different measurement identified over time as being one, or some other such statement (Peres, 1993, p. 290). General relativity uses Riemannian manifolds, but it is an open question whether this geometric picture is more or less adequate than a different point of view based on holography. Poincaré famously tried to motivate the inevitability of Riemannian and even Euclidian geometry (Poincaré, 1902), but any a priori argument, as it seems from the history of science, ends up being refuted. So on what can we build a foundation of physical theories?

Not on much; at least, not on any ontological commitment about the world. Admitting any such commitment places us in the context of a wired brain: here and now we may simply lack the imagination needed to get rid of a well-wired belief. So what remains? The mathematical structure of physical theories, plus the relations between theories based on their mathematics. This does not involve any notion of entities existing in the world "behind" the observable phenomena and independently of the description given to them by physical theories.

2 Epistemological modesty

Writing about the measurement problem in quantum mechanics as early as 1939, London and Bauer emphasized that physics can make an impact on philosophy insofar as it makes "negative philosophical discoveries" (London and Bauer, 1939), i.e., following the advent of physical knowledge certain philosophical points of view cannot be maintained any more. It also means that physical science does not warrant positive metaphysical assertions of the kind, "The true ontology of the world is so and so." But physical theories, for sure, rely on certain first principles. Aren't these axioms our best candidates for being the fundamental truth about reality? We submit that first principles of physical theories should not be necessarily taken as ultimate truths about nature. Independently of one's ontological commitments, they may only retain a minimal epistemic status of being postulated for the purpose of building up a specific theory.

As in the 19th-century mathematics, in theoretical physics the axiomatic method is to be separated from the attitude that the Greeks had toward axioms: that they represent the truth about reality. Much of the progress of mathematics is due to understanding that an axiom may no longer be considered an ultimate truth, but merely a fundamental structural element, i.e., an assumption that lies at the basis of a certain theoretical structure. In mathematics, after departing from the Greek concept of axiom, "not only geometry, but many other, even very abstract, theories have been axiomatized, and the axiomatic method has become a powerful tool for mathematical research, as well as a means of organizing the immense field of mathematical knowledge which thereby can be made more surveyable" (Heyting, 1963). A similar attitude is to be taken with respect to axioms used for reconstructing a physical theory. The methodological precept that gives a minimal status to the first principles in a reconstruction program, runs as follows (Grinbaum, 2007):

- If the theory itself does not tell you that the states of the system (or any other variables) are ontic, then do not take them to be ontic.

I call this an attitude of *epistemological modesty*. It is more economical to treat the foundational principles as axioms *hic et nunc*, i.e., in a given theoretical description. Epistemological modesty requires that one brackets his or her personal motives for the choice of first principles, which merely become axiomatic statements in the reconstruction of a given theory. Unambiguous derivation of the theory's formalism is detached from the question of reality of the world that the theory describes, with respect to which one is free to hold a personal belief of any kind unless it is contradicted by a "negative philosophical discovery".

3 Observers as informational agents

Historically quantum physics has been predominantly conceived as theory of non-classic waves and particles, while special relativity was thought of as a theory of moving rods and clocks. Fock argues that such views have only been well-motivated at the early stages of the development of these theories when a few experimental results were available and the dominant philosophy was still couched in the physics that preceded the creation of the new theories. Today a minimal description of what quantum mechanics is would have it as a mathematical formalism which, when applied to physical setups, gives very accurate predictions for the results of experiments. This standard formalism relies on a cut between the observer and the system being observed (Dirac, 1930; von Neumann, 1932). No ruse can remove such a "shifty split" (Bell, 1990) of the world into two parts: the formalism only applies if the observer and the system are demarcated as two separate entities. Physical properties of the system, on one side of the split, do not exist independently of the observer, on the other side of the split, and can only be instantiated during the observation, or 'measurement', of some dynamical variable of the system chosen by the observer.

What is important about the observer? Only his function of an informational agent, not his physical constituency. The need to refer to consciousness exists insofar as only consciousness can distinguish a mere physical correlation, e.g. of an external system with the observer's eye, from the information actually available to the observer, i.e. such that he can act upon in the future. Other characteristics are irrelevant: say, the observer's age plays no role ("there is little chance of making a big mistake if one does not know [the observer's] age" (London and Bauer, 1939, p. 43)). A sufficiently complex computer, which has a capacity to discern data coming from a measuring device and to extract relevant knowledge from this data, can also act as an observer. What, then, is a universal observer, i.e. an observer capable of receiving data from different measuring devices? Such an observer must be able to adapt to the specifics of interaction with a particular device as a measuring instrument. A simple interaction that established a correlation is always possible, because both the observer and the measuring device are physical systems. But something else must be added: the capacity of the observer to extract relevant knowledge from the data correlated with the observed physical system.

This adaption to the specifics of the interaction requires that the observer know how to read a measurement result from the device. When a new measurement device is constructed, this knowledge can only be possessed by its creator, whether a human being, a machine or a creature of intermediate stature. The creator communicates with other systems and gives them instructions for the use of his new device as a measurement instrument. For instance, if the creator is a human being, he can program a computer so that the computer can read measurement results; alternatively, the creator may just tell another person how to use it. If the creator is a computer program, it may run tests of the experimental system and communicate their results to the other computer or a human being until this second observer acquires a capacity to run tests on the same system whose results will testify of his perfect mastery of the measurement instrument. In both cases communication is essential. If multiple observers are required to be able to use a measurement device, then the device's creator or first user must necessarily communicate his skills (or what we perceive as a "skill") to the other observers.

Can an observer just learn by himself how to use a measurement device, without communicating with anyone or anything? Of course, he can. In this case, however, provided that the apparatus does not break, the observer's own way of using it may differ from somebody else's. Indeed, two unconnected observers may resort to two very different ways of using the same physical device as a measurement apparatus. An arrow may point to a particular position on the clock, but for somebody else the arrow's movement may convey a more meaningful message. Communication in either form is needed for the consistency between measurement results and for the agreement between observers.

How can two observers interact? If they are humans, they can use speech; communication is therefore linguistic. If observers are arbitrary physical systems, then the interactions must go as any interaction between physical systems, i.e. through an interaction potential. After some time T characteristic of this potential the observers will become correlated.

We now wish to avoid postulating that observers are human beings but still to preserve their specificity as observers. The first observer knows that the second one is indeed an observer and not an arbitrary system. This means that O_1 knows that O_2 has committed a unique measurement on system S. What are the consequences for O_1? Indeed, O_1 could describe this knowledge via probabilities: to every result obtained by O_2, O_1 attributes a subjective probability that this result has occurred. But O_1 could also do it differently. If the result obtained by O_1 in measuring S is x_1, then O_1 can form a belief that whoever else consequently observes this system, and O_2 in particular, will obtain the same result. This is a matter of confidence, whose roots aren't grounded in the empirical data coming from the observation in question. Observer O_1 refuses to apply probabilistic reasoning with respect to other observers, because he knows something about them: they are not merely physical systems but *observers*.

Therefore measurement is not a dynamical process involving an interaction potential. It is a primitive concept, which is a matter of trust or convention between observers. Such trust comes about in different forms for each type of observer-system; e.g., for human observers it may be related to language. Not only measurement is not a dynamical process described; it must not be treated as 'physical' at all. Only the correlation created by the interaction potential is physical but it is an interaction as good as any. If there is something special about observers that distinguishes them from arbitrary physical systems, it cannot be read from physical data. If this 'something special' is memory, which is just a classical system whose states can be read at a later time, something must point out to a particular set of the degrees of freedom as constituting such memory. Observers are not self-transparent to themselves and they know that other systems are observers not because of some physical fact, but because it is a question of convention and, metaphorically speaking, belief. There is no physical counterpart to knowing that O_1 has interacted with observer O_2 rather than a physical system O_2. For instance, physical states might be different from mathematically allowed states. The correlation that O_1 established in the measurement process is read through the prism of O_1's theory of O_2 or of linguistic convention, which enables him to acquire information. If O_1 believes that this procedure is the same for all observers, he will effectively believe that all observers should agree on the reading of measurement results.

4 Epistemic loops

For a long time many physicists have lacked understanding of the epistemological lesson coming from the necessity of the cut between the observer and the observed. Einstein, for instance, believed all his life that the postulate of the existence of a particle or a quantum is a basic axiom of the physics. In a letter to Born as late as 1948 he writes (Born, 1971, p. 164):

> We all of us have some idea of what the basic axioms in physics will turn out to be. The quantum or the particle will surely be one amongst them; the field, in Faraday's or Maxwell's sense, could possibly be, but it is not certain.

This is to say that Einstein believed that a proper physical theory must be based on the ontology of certain physical systems, such as particles or fields, and will build upon the known facts about these elementary systems in order to provide an account of all physical phenomena. In another illuminating piece of his late writing, Einstein at the same time acknowledges the necessity of the epistemological cut but fails to recognize its implications for the way new physical theories must be thought of:

> One is struck [by the fact] that the theory [of special relativity] . . . introduces two kinds of physical things, i.e., (1) measuring rods and clocks, (2) all other things, e.g., the electromagnetic field, the material point, etc. This, in a certain sense, is inconsistent; strictly speaking measuring rods and clocks would have to be represented as solutions of the basic equations (objects consisting of moving atomic configurations), not, as it were, as theoretically self-sufficient entities. However, the procedure justifies itself because it was clear from the very beginning that the postulates of the theory are not strong enough to deduce from them sufficiently complete equations . . . in order to base upon such a foundation a theory of measuring rods and clocks. (Einstein, 1969, p. 59)

Epistemologically, it is unreasonable to expect, as Einstein did, that the theory of measuring rods and clocks could be based on a set of yet stronger postulates that would, at the same time, provide also an account of all physical phenomena measured by means of these rods and clocks. To see why Einstein found himself at an impasse, albeit an unnecessary one, consider the following schematic representation of physical theories. Assume that phenomena are best described by theories that are interconnected in the form of loop. Any particular theory is represented by cutting the loop at some point and thus separating the target object of the theory from the theory's presuppositions. Due to the necessity of the cut, it is impossible to give a theoretical description of the loop as a whole. Now, when the position of the cut is fixed, some elements of the loop are treated as objects of the theory, while other elements fall into the domain of meta-theory. At another loop cut, those elements exchange roles: the ones that had been explanans become explanandum, and those that had previously been explanandum become explanans. Different theories do not form a pyramid which is reduced to yet more and more fundamental theories with "stronger postulates"; on the contrary, for the purposes of each theory, a part of the loop must be taken as a given, and the relation between theories is the one of mutual illumination rather than that of reduction. Metatheory of a given theory, i.e., the part of the loop kept fixed in the task of reconstructing the theory in question, is no more and no less than the theory that explains the functioning of measuring devices of the theory that is being reconstructed. For the purposes of the reconstruction of a given theory, the loop view demonstrates how measuring devices of the theory can be assumed to be meta-theoretic and abstract in Fock's sense while driving the reconstruction; but in a different loop cut, the same measuring devices become themselves objects of another theory that would explain their functioning.

Consider the loop between physical theory and information. Physics and information mutually constrain each other, and every theory will give an account of but a part of the loop, leaving the other part for meta-theoretic assumptions. In the cut shown on Figure 1 information lies in the meta-theory of the physical theory, and physics is therefore based on information. In a different loop cut (Figure 2), informational agents are physical beings, and one can describe their storage of, and operation with, information, by means of effective theories that are reduced, or reducible in principle, to physical theory.

Without recognizing the importance of the cut one cannot fully appreciate the unbridgeable (within a given theory) separation between the observer and the observed. The loop view allows one to make sense of assertions that mark a no small change in the conception of physics, e.g., of Bub's idea that information must be recognized as "a new sort of physical entity, not reducible to the motion of particles and fields" (Bub, 2004). In the loop epistemology, however, information is an entity, but not a physical entity or object of physical theory like particles or fields are. Were information a basic *physical* entity, the information-theoretic viewpoint would then do nothing to approach the problem of giving quantum *physics* a foundation, for it would need to provide a inevitably circular argument taking, at the same time, information to be a fundamental irreducible concept, and explaining how information can be stored, or operated with, physically. The only way to avoid circularity is through removing information into metatheory. When one does so consistently, the conventional physical concepts such as particles and fields are reduced to information, not put along with it on equal grounds; but information itself, in another loop cut, can be too treated as a derivative notion, in another theory that would itself take particles and fields as givens.

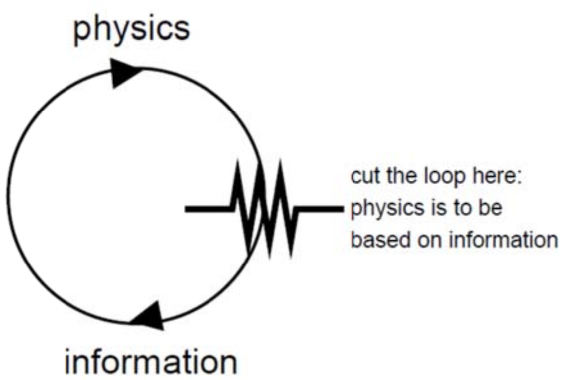

Figure 1: Loop cut: physics is informational

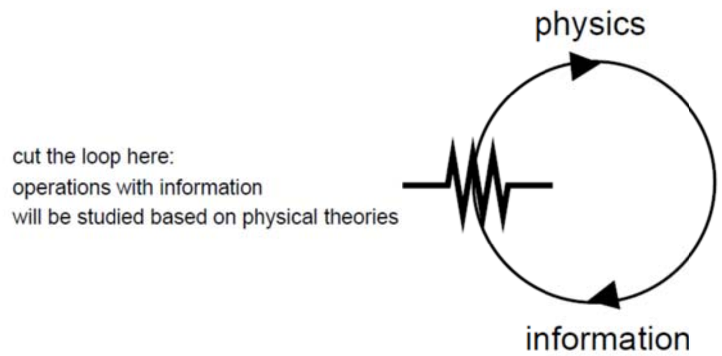

Figure 2: Loop cut: information is physical

In the loop cut of Figure 2 the question of reconstruction of physical theory is meaningless, because physical theory is taken for granted. Indeed, once a particular loop cut is assumed, it is a *logical error* to ask questions that only make sense in a different loop cut. For instance, the critique of information-theoretic reconstructions motivated among some physicists mainly by Landauer's "information is physical" (Landauer, 1987) can be avoided by adopting the loop view. Einstein's plea for "stronger postulates" is then a mere epistemological illusion. Fervent defender of such view would be led to a logical impasse, one to consider that it is possible to have a physical theory that would include within itself a description of the physical structure of its own measurement devices.

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