Exophysics, Endophysics, and Beyond

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Abstract

The distinction of external (exo) and internal (endo) perspectives is addressed with respect to the issues of observation and measurement in quantum theory. It is demonstrated how the exo/endo-terminology can be fruitfully applied to two equally important concepts of reality in the quantum world: local (common sense) reality and holistic (nonlocal) reality. Basic elements of the exo/endo-distinction are then used to interpret certain features concerning the issues of time, histories, and presence.

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1 Introduction

The distinction of inside and outside is one of the most fundamental distinctions at all. A most straightforward way to make such a distinction is by definition of a suitable boundary of a system. With respect to such a boundary (or an interface) it is at least in principle easy to distinguish an inside from an outside of the system. Of course, problems are inevitable as soon as logical complications as provided by Klein bottles or Escher figures have to be considered or when fractal boundaries play a role. The subjects of this contribution are presented in such a way that corresponding problems are avoided (as far as possible).

If an endo/exo-distinction is intended to refer to internal and external modes of observation and knowledge rather than refering to a simple inside/outside-distinction, the situation immediately gets more complicated. Quite a number of different approaches corresponding to associated problems are collected and discussed in the volume *Inside Versus Outside* (see especially the comparative discussion in the introduction to this volume [1]). Other ideas and viewpoints on related topics can be found in [2]. Among the many different approaches that are possible I intend to discuss a specific one which is anchored in modern algebraic quantum theory and has been outlined in [3,4]. The relationship of this approach to basic systematic elements of European philosophical tradition is addressed in [5].

To my knowledge the mentioned approach is the only one that is both mathematically formalized to a fairly comprehensive extent and conceptually consistent with the best confirmed physical theory we know today: quantum theory. Moreover, ways toward its applicability to the study of (classical) complex systems [6] have recently been indicated. Main advantages of this approach are its tight relationship to contemporary physical knowledge together with its potential for (controlled) speculations beyond this knowledge which do not have to start from scratch. The capability to work within a developed mathematical formalism is highly desirable if non- or even counter-intuitive features are to be expected. Major disadvantage: the formalism of algebraic quantum theory is not always easy to handle for specific applications.

A basic epistemological element, a so-called regulative principle of all branches of physics is the Cartesian distinction (cut) of matter and mind [7]. In more modest terms, it indicates the difference between data (facts) and models (theories) and is *not* identical with our concept of an endo/exo-distinction. From the point of view of modern science, the Cartesian distinction does not imply ontological committments. It should rather be considered as a methodological tool, an abstraction that "generates" the concept of a material world as opposed to that of a mental world. Without this abstraction the development and the success of modern science and technology are inconceivable. The basic principles of conventional scientific experimentation exclude anything beyond the material world as an object of an empirically testable scientific theory. Although the Cartesian distinction is never mentioned explicitly in scientific publications of whatever kind, it is a most important implicit principle of modern science.

This is particularly true for quantum theory. The formal apparatus of quantum theory does not at any place refer to the mental world of human observers, to their cognitive capabilities or psychological constitution. On the other hand, it would certainly be an exaggeration to say that the current status of quantum theory is satisfactory in every possible respect. For instance, fundamental conceptual (not only formal) questions arise in the well-known measurement problem, i.e., the distinction of an object of measurement from its environment (including measuring devices) as well as their interaction. In general, an inanimate environment can act as a "measuring device", though in a non-intentional manner. As soon as *controlled* experiments are considered, it is clear that issues like the design of an experiment, the choice of observables of interest, or the interpretation of the results of a measurement are unavoidable. They depend on decisions based on the intentions of human observers and are not explicitly dealt with by the formalism.

However, to admit that these problems exist must not be mixed up with the belief that quantum theory is already a theory of matter *and* mind. Such a belief is sometimes advocated, but it has not lead to anything else than non-testable hypotheses so far. Accepting the Cartesian distinction as a regulative principle for contemporary physics implies that this physics refers to the material world and is not claimed to be applicable to anything beyond. Alluding to Einstein's conviction of an alleged incompleteness of quantum mechanics, Pauli once wrote in his privately distributed essay *Modern Examples of Background Physics* [8]: "This does not indicate an incompleteness of quantum theory within physics, but an incompleteness of physics within the totality of life".

2 Exo- and Endo-Aspects in Quantum Theory

The process of measurement is one of the central problems, if not *the* problem of quantum mechanics. Although much progress has been achieved with respect to its understanding since the early days of pioneer quantum mechanics, the problem in total is still not finally solved. However, empirical results and modern formulations of quantum theory allow us to state it more precisely than ever before. One of the empirical cornerstones of our present understanding of measurement is the existence of nonlocal (Einstein-Podolsky-Rosen, EPR) correlations [9-11] which are ubiquitous in any system requiring a description in terms of a non-commutative algebra of observables.[1]

In a sloppy parlance, one might say that EPR correlations correlate everything

[1]A non-commutative algebra of observables reflects the fact that the operators representing certain properties of a state of a system do not commute. In another jargon, such properties are called mutually incommensurable. Propositions refering to them are incompatible – which means that only one of two propositions about mutually incommensurable properties can have a definite truth value (true or false) for a given situation.

with everything else, thus suggesting the notion of a holistic concept of reality at a very basic level. But such a statement would be misleading without precise qualifications concerning its range of relevance. Quantum mechanical holism is but one reality concept that modern quantum theory needs to account for its empirical results. Another one, which is equally important, is the ("common sense") concept of a local reality, which was considered to be *the* reality for centuries of physicists from Newton to Einstein. Today we know that the two concepts refer to two basically different situations. Both together are necessary for a comprehensive description, none of them is sufficient on its own.[2] In the framework of algebraic quantum theory, the difference between them is rigorously formalized and clearly understood. It can be related to two different state concepts; namely those of ontic and epistemic states. This terminology has originally been suggested by Scheibe in 1964 [13], and it has turned out as a powerful and attractive tool to understand the differences and similarities of various interpretational schemes in quantum theory. Avoiding details I adopt the following compact characterizations [3,4]:

Ontic states in an ontic state space describe all properties of a physical system *completely.* ("Completeness" in this context means that an ontic state is "just the way it is", without any reference to epistemic knowledge or ignorance.) Ontic states are the referents of *individual* descriptions, their properties are abstract and potential and can be formalized by *intrinsic observables* as elements of a C^*-algebra. Ontic states in this sense are *operationally inaccessible. Epistemic states* describe *our (usually incomplete) knowledge* of the properties of a physical system, i.e. based on a finite partition of the relevant epistemic state space. The referents of *statistical* descriptions are epistemic states, their properties are concrete and actual and can be formalized by *contextual observables* as elements of a W^*-algebra. Epistemic states in this sense are *operationally accessible.*

One of the most striking differences between the two kinds of states is their difference concerning operational access, i.e. observability and measurability. At first sight it might appear pointless to keep a level of description which is not related to what can be verified empirically. However, a most appealing feature at this ontic level is the existence of first principles and universal laws that cannot be obtained at the epistemic level. Furthermore, it is possible to rigorously deduce (to "GNS-construct" [4]) a proper epistemic description from the ontic description if enough details about the empirically given situation are known. This is particularly important and useful for the treatment of open and macroscopic (quantum) systems.

The distinction of ontic and epistemic states provides an important clue to understand the distinction between a holistic and a local concept of reality. Ontic states and intrinsic observables refer to a holistic concept of reality and are operationally inaccessible, whereas epistemic states and contextual observables refer to

[2]The core of the well-known Bohr-Einstein discussions in the 1920s and 1930s [12] can be traced down to the belief that only one of the mentioned concepts of reality can be relevant. As far as I know neither Bohr nor Einstein have ever explicitly addressed the question whether different concepts of reality might "simply" have different ranges of relevance.

a local concept of reality and are operationally accessible. It is exactly the process of measurement which represents the bridge between the two. Measurement suppresses (or minimizes, respectively) the EPR correlations constituting a holistic reality and provides a level of description to which one can associate a local concept of reality with locally separate (or "approximately" separate, respectively) objects. In this sense it is justified to say that measurement generates objects by introducing a *Heisenberg cut* as a metaphor for the suppression of EPR correlations.[3]

Another way to look at the distinction of ontic and epistemic states and the associated algebras of observables is the following. The ontic holistic reality of quantum theory is related to all sorts of inquiries into an independent ("when nobody looks") reality of the outside world. Focusing at an epistemic local reality expresses a change of perspective to the effect that the question "What is the outside world?" is replaced by "What can we know about the outside world?". Philosophically the distinction between these two questions is very much in the spirit of Kant's distinction of transcendental idealism and empirical realism. As an empirical science, physics addresses only questions of the second kind. But on the other hand, the mathematical formalism that constitutes the formal basis of physics often leads into a way of thinking very much in accordance with the first kind of question. For a long time in the history of science the two questions have not been distinguished explicitly. Scientists and philosophers of science did not much worry about a possible difference between the world "as it really is", ontically, and the world "as it appears to us", epistemically.

It is precisely the distinction between an epistemic and an ontic level of description, which is covered by the distinction between external (exo) and internal (endo) perspectives in modern quantum theory. In such a conceptual framework, the notion of an observation is strictly irrelevant as soon as the epistemic level of a local reality is left. An observer is always an external observer with respect to the observed object; an external viewpoint is a logical precondition for the faculty of observation.[4] Only in a local reality we have objects separated from their environment, and only in a local reality we have interactions and signals between such objects. At the ontic, holistic level of reality the notion of participation is appropriate in order to indicate that from an endo-"perspective" there are no objects or signals between them to

[3]Heisenberg introduced the notion of a cut ("Schnitt") in a paper of 1936 [14], talking about a "cut between the system to be observed and the measuring devices". For an application of this metaphor to the problem of pattern recognition in complex systems compare [6,15]. The problem of measurement is inseparably related to the Heisenberg cut insofar as it deals with the abstraction by which local objects are "generated".

[4]Rigorously speaking there is no room for concepts like "endo-observation" in such a scheme of thinking. For instance, "internal observers" in the sense of [16,17] refer to a local epistemic exo-reality. Possible relationships between a "local endo-perspective" according to [16,17] and a holistic endo-perspective as advocated here might become clearer if an endo/exo-distinction with respect to the issue of time is explicitly taken into account (for some first and very preliminary indications see next section). In addition it should be kept in mind that the approach discussed in this paper disregards problems related to the Cartesian cut (compare the preceding section).

be observed. Measurement as the transition from an ontic, holistic reality to an epistemic, local reality is a paradigmatic example for a process of objectification in a very elementary sense [5].

3 Time, Histories, and Presence

So far, the whole discussion about the Heisenberg cut can be boiled down to a clear-cut distinction of two different concepts of material reality, separated by the issue of measurement. But the measurement *process* itself, in its dynamical, not only in its structural and logical features, is not yet entirely understood. Up to now we do not have a formally rigorous, logically consistent, and conceptually satisfying description of what is "really" going on in a system when a local concept of reality replaces a holistic concept of reality since local objects are constituted. Assigning invariant Hamiltonian one-parameter groups to the reversible evolution of ontic states and dynamical one-parameter semigroups to the irreversible evolution of epistemic states [3,4] imposes a deep problem for the dynamics of the transition between the two state concepts [18]. Since the measurement process (by definition) includes the act leading from an ontic to an epistemic level, the dynamics of this act cannot be distinctly associated with the dynamics according to one of these levels only. The question may be asked whether another kind of approach is needed to give a truly dynamical picture of measurement which is no longer based on the concept of states.

This point touches an age-old bias in the history of European philosophy and science – the bias that prefers spatial concepts at the expense of temporal ones. In this context it is interesting to note that the counterintuitive features of quantum holism are almost always discussed in terms of *spatially* distinguishable or indistinguishable states, respectively, rather than distinguishable or indistinguishable *dynamics* (e.g., trajectories). The latter issue is closely related to the notorious problem of a proper time observable rather than time as a parameter. More recently, there are two promising approaches which focus on this problem from different starting points. The first one is the search for a time operator not commuting with other observables, thus giving rise to temporal nonlocality as a consequence of this non-commutativity. Such a line of research is one of the elements of the work of Antoniou, Misra, Prigogine and collaborators [19-22]. Another way toward temporal nonlocality is based on the formal framework of the "histories"–approach to quantum theory [23] and tries to establish temporally nonlocal "inconsistent histories" as a consequence of a temporal version of Bell's inequalities [24,25].[5]

Conceding the preliminary status of a "temporal nonlocality" in this sense, it is nevertheless fair to say that a corresponding kind of temporal holism cannot possibly be interpreted in terms of ontic versus epistemic states alone. What is needed in addition are concepts transfering this distinction to a temporal level, something like

[5] It is not yet clear how these two approaches are related to each other. For a formally oriented discussion of both of them and some of their problems see [26].

ontic and epistemic dynamics without immediate reference to states. In this respect, the terminology of internal (endo) and external (exo) viewpoints suggests itself as an attractive tool for a joint distinction concerning states *and* dynamics. Briefly, a local exo-perspective in time allows us to look back at certain distinct elements of the past, or to predict certain distinct elements of the future. This is only possible if past and future are not temporally correlated with our presence. From a holistic endo-perspective such a distinction of separate time slices is prevented by temporal nonlocality. Such a situation refers to a participatory "experience" of presence without well-defined temporal sequences. There is no such concept like a closed history of events, nor are there individual events, in a holistic endo-temporal reality. It is the transition from this endo-presence to an observational exo-perspective that provides closed histories by a *temporal* cut separating certain sequences of events from their *temporal* environment. In this way past and future are "created" as distinct modes of temporality.

20th century's philosophy has witnessed a steady but off-mainstream interest in concepts of time that can be covered by the notion of an "internal time". One of the early references is, of course, Bergson [27]; more recent authors are Gebser [28] or Prigogine in his philosophically oriented publications [29]. The protagonist of internal time, however, is Whitehead [30]. He developed his philosophy of organism long before quantum theory arrived at its fascinating insights into the concept of a holistic reality as opposed to a local reality together with its possible implications for the study of time. For Whitehead the ultimate concrete entities in the universe are the "actual occasions". Actual occasions are not "objects" in the sense of building blocks of a local reality, but they are nonlocally and inseparately related to each other by so-called "prehensions". An actual occasion occupies a definite spatial region, and its temporal duration is finite. Both its temporal and spatial extension depend on contexts given by the prehensions.

Whitehead's philosophy of organism is tightly connected with his theory of perception. The finite duration of an actual occasion corresponds to the duration of the so-called "specious present", a term introduced earlier by William James. Whitehead's concept of the specious present resembles very closely the idea of an extended duration of "presence" in the sense of current trends in cognitive science. At one level such a "presence" may correspond to the syntactic elementary integration units of approximately 30msec; at another level, an interesting candidate is the 3sec interval of semantically coherent perception [31]. Neuropsychological results concerning the 30msec window do phenomenologically resemble some of the aspects of temporal nonlocality as addressed above.[6] From an endo-perspective, the sequence of individual events separated by temporal distances smaller than time intervals of the order of 30msec cannot be determined [32]. On the other hand, it is of course possible to

[6]It would certainly be premature to ascribe these results to temporal nonlocality in a formal physical sense. But at a speculative level, such a possibility should also not be excluded too early. Whitehead's philosophy represents a serious attempt to address physical nonlocality in time and the "specious present" in perception within one and the same conceptual framework.

determine the distance of such events and their temporal sequence from an external point of view. Another very interesting perspective in the same context concerns the relationship between neurophysiological and neuropsychological results as an example for the fundamental problem of relationships between matter and mind, across the Cartesian cut.

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