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On the “negative utility” of Ernst Cassirer's philosophy of physics: An application to the EPR argument

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A B S T R A C T

This paper tries to reconstruct Ernst Cassirer's potential reception of the EPR argument, as exposed by Einstein in his letter to Cassirer of March 1937. It is shown that, in conformity with his transcendental epistemology taking the conditions of accessibility as constitutive of the quantum object, Cassirer would probably have rejected the argument. Indeed, Cassirer would probably not have subscribed to its separability/local causality presupposition (which goes against his interpretation of the quantum formalism as a self-sufficient condition constitutive of the quantum object, without any reliance on spatial intuition), nor to its completeness requirement (as his partial endorsement of Bohr's complementarity, and his rejection of the Kantian "idea of complete determination", illustrate). By rejecting both of its premises, Cassirer's philosophy of physics thus enables to escape the EPR dilemma, and exhibits what, in Kantian terms, might be called a "negative utility" with respect to physical science. A further investigation of the anti-reductionist utility of Cassirer's systematic philosophy with respect to physics and other "symbolic forms" is finally suggested.

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1. Introduction and historical setting

There has been, in the current debates related to the interpretation of quantum physics and structuralism, a renewed interested in Neo-Kantian approaches to the history and philosophy of physics (see e.g. Cei & French, 2009a, 2009b; French & Ladyman, 2011). In this context, Ernst Cassirer's critical theory of physical knowledge remains under-appreciated—and especially his interpretation of quantum theory as exposed in his book *Determinismus und Indeterminismus in der modernen Physik. Historische und systematische Studien zum Kausalproblem* (Cassirer, 1936)[1] (although Ryckman, 2015 has recently given a very insightful account of it). Indeed, Cassirer's philosophy of physics might well be of interest for two kinds of philosophical issues in this context, namely: ontological issues, bearing on the implications of quantum physics on the debate about scientific realism and transcendental idealism; and methodological issues, related to the kind of relationship philosophy could, or should, entertain with physics (considered as distinct disciplines). In the following, although I will make occasional references to the former, I shall essentially concentrate on the latter. For this I shall reconstruct Cassirer's most probable reception of Einstein's famous EPR argument (which, to the best of my knowledge, Cassirer did not address in his writings), in order to show its critical “utility” (more about this below) with respect to a more classical, field theory-based conception.

In a letter dated from the 16th of March 1937 (in Cassirer, 2009, 158–160), Einstein praises Cassirer's recently published *D&I*. He then sketches an argument intended to show the incompleteness of quantum theory, by making use of a property characteristic of its tensorial formalism, namely the correlation or entanglement (as it is called today) of the states of two sub-systems of one global quantum system. This argument essentially summarizes the core argument of the EPR paper (famously designated by the acronym of its authors, Einstein, Podolsky and Rosen), published less than two years earlier (Einstein, Podolsky, & Rosen, 1935). My intention here is not to discuss this argument as such (otherwise the object of an overwhelming secondary literature), but, rather, to try to

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[1] Hereafter referred to as *D&I*. There is an English translation available (Cassirer, [1936] 1956), not always very accurate. In the following, I shall refer to the 1957 joint edition of *D&I* with Cassirer's other main epistemological work, dedicated to Einstein's theory of relativity (*Zur Einsteinschen Relativitätstheorie. Erkenntnistheoretische Betrachtungen*, Cassirer, 1921, hereafter *ZER*), entitled *Zur modernen Physik* (Cassirer, [1921, 1936] 1957).

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reconstitute Cassirer's most probable reception of it. Indeed, there is, as far as I know, no trace of this reception in Cassirer's writings, neither in his books, nor in his correspondence—except a short remark by H. Margenau in his preface to the English translation of *D&I*, where he states (without further elaborating) that "Cassirer tended to accept [the view that quantum mechanical description does not have to be supplemented by hidden variables[2]] on the evidence he had available, which was less complete than it is now." (in Cassirer, [1936] 1956, xviii). Although the EPR article figures in the references cited at the end of *D&I*, as "part of Cassirer's intended bibliography in 1945" (in Cassirer, [1936] 1956, 214) according to Margenau, no reference is made to it inside *D&I*. Margenau indicates that he collaborated with Cassirer "in the preparation of a bibliography and a final chapter on developments concerning the causality problem after 1936", but he did not, unfortunately, publish this material, because "the writing did not reach a stage at which the result could carry Cassirer's benediction" (in Cassirer, [1936] 1956, ix). Thus, it is unclear whether Cassirer had cognizance of the EPR paper when he wrote *D&I* (which is theoretically possible, since he explains in his foreword that he finished the manuscript in April 1936) and preferred not to mention it, or if he had not (which is also possible because of the troubled circumstances he was in at that time).

Nevertheless, I hope to show, drawing especially on *D&I*, that Cassirer would probably have rejected the EPR argument. What is the use of such a reconstruction? Apart from the historical anecdote (would Cassirer have dared to disagree with Einstein, whom he held in high esteem otherwise?), it is intended to show, to put it in Kantian terms (see e.g. Kant, 1781, A795/1787, B823), the potential "usefulness" or "utility" (*Nutzen*) of Cassirer's philosophy with respect to physical knowledge.[3] More exactly, it is intended to show, not its "positive utility" in the sense that it would contribute to the "widening" (*Erweiterung*) of our physical knowledge; but, more modestly, its "negative utility", in so far as it is used for its "correction" (*Läuterung*) or "rectification" (*Berichtigung*) [*ibid.*]. In others words, philosophy understood in this *critical* sense (which is, according to the Marburg school of Neo-Kantianism to which Cassirer belonged, the true meaning of Kant's "transcendental method" in its *analytic* sense, starting from the *factum* of science up to its "conditions of possibility") shall identify the *presuppositions* which the scientist uses in its theorizing activity—thereby preventing all undue metaphysics.[4]

2. Einstein's epistolary version of the EPR argument

Einstein's summary of the argument in his letter to Cassirer is rather condensed: it has nonetheless the advantage of concentrating on the core argument of the EPR paper, whose structure is otherwise rather complicated. Again, what I am interested in here is not so much the original EPR paper itself (Fine, 2012 has shown how dissatisfied with its formulation Einstein was) than its core *presuppositions*, in order to see if Cassirer would have subscribed to them. As we shall see, Einstein's letter has the advantage of dispensing with all the unnecessary hypotheses of the EPR paper (the criterion of reality, the complicated argument over the simultaneous values for complementary quantities); only the separability and local causality presuppositions remain (on the dispensability of these, see the end of this section).

In his letter, Einstein considers a quantum system made up of two "material points" (i.e. particles) 1 and 2, which collide at t_0 and are then separated. The state of the global system is described by the wave function $\psi_{12}(t)$, whose temporal evolution is governed by Schrödinger's equation, and thus known for all $t \geq t_0$, if the initial condition $\psi_{12}(t_0)$ is known (recall that Schrödinger's equation is a partial differential equation of first order with respect to time). Then comes the correlation argument: a measurement undertaken on particle 1 (contrary to the EPR article, the type of observable measured is not specified), together with the knowledge of $\psi_{12}(t)$, enables us to determine the state function ψ_2 characterizing particle 2 (without any measurement carried out on this latter particle).[5] But it is possible to undertake *another* measurement on particle 1, which correspondingly provides *another* state function ψ_2. At that point Einstein makes a fundamental assumption:

> Now it seems inevitable [*unausweichlich*] to me to assume that, through a measurement in 1, one cannot exert any influence on the physical state of mass point 2, since both mass points are indeed completely separated from each other [*völlig voneinander getrennt*]. At least this decidedly contradicts my physical instinct to assume such an action at a distance [*Fernwirkung*].[6] (in Cassirer, 2009, 159).

This assumption is in fact two-fold:

1. The first assumption is explicit: a measurement in point 1 cannot exert any physical influence on a measurement carried out in point 2 which is *spatially* separated from it. In other (relativistic) words, there can be no causal influence between two points separated by a space-like interval. Fine (2012) calls this assumption "locality", but it should more accurately be called *local* (or *relativistic*) *causality*.[7] For the sake of clarity, let us keep this latter designation in the following.
2. The second assumption is implicit (as it is in the EPR paper): the two mass points are supposed to have independent physical existences. Let us call this assumption, following Fine (2012), that of *separability*. Thus Einstein talks of the measurement on 1 as exerting an "influence on the physical state of mass point 2", which is "completely separated" from the former, thereby granting independent physical existence to each sub-system of

[2] Note that the EPR argument itself does not explicitly propose the introduction of hidden variables, but it has been used by proponents of this approach.

[3] In Kant, the "utility" considered is that of the "critique", as applied to (and at the same time performed by) "pure reason", the sole source of *a priori* knowledge, which includes both (theoretical) philosophy and "rational physics" (what we would call today theoretical physics).

[4] The *prospective* application of Cassirer's transcendental method which I intend to perform here should thus be taken in the most common sense of this word (i.e. to apply Cassirer's conception to a case which he has not himself treated). In particular, it should not be taken in the sense of Friedman's (2001, 2010) "*prospective* transhistorical rationality", in which philosophy has a productive or creative role with respect to science in suggesting a new paradigm (as seen from the earlier one). This latter sense, indeed, is more akin to (my re-conceptualized version of) Kant's "positive utility".

[5] This is because the original global state, which is a (potentially infinite) sum of factorized states, reduces to one term (the product of the state corresponding to the value measured for particle 1, with the state corresponding to particle 2). Thus the indirect measurement procedure which is here used to assign a state function to particle 2 without effectively measuring it is based on the principle of superposition (together with the process of reduction of the wave packet, corresponding to the measurement performed on 1).

[6] Further in the letter Einstein even calls it a "telepathic reciprocal action [*Wechselwirkung*]" between the two separate mass points (in Cassirer, 2009, 160).

[7] In the strict sense, locality should only designate the property of a physical system (a particle) to be localizable in space-time (which, as is well known, is not the case of quantum particles, including when they are considered individually). In classical mechanics, there can be locality (as for classical particles) or non-locality (as for classical waves), but there is in any case local causality (the non-locality of classical waves still respecting relativistic causality). In quantum mechanics, particles can exhibit properties either of corpuscles or of waves: thus there is non-locality, and in addition non-local causality. Note, however, that quantum non-locality is not *prima facie* incompatible with a quantum local-causality: it is precisely what entanglement set-ups of the EPR type show.

the global entangled system.

From this two-fold assumption Einstein then deduces “that the ‘real physical state’ [*der physikalische* “*wirkliche Zustand*”: this is the separability part] of 2 cannot depend [this is the local causality part] on what kind of measurement I perform on 1. But since in both cases we end up with two fully different ψ_2, then two fully different ψ-functions ψ_2 belong to the *same* [here are integrated both separability and local causality] physical state of 2.” (in Cassirer, 2009, 159). But this state of affairs finally contradicts Einstein's *completeness* requirement, which consists in the *univocality* of the theoretical representation of reality: “But this is incompatible with the conception that ψ_2 be a complete description [*vollständige Beschreibung*] of the physical state of point 2; for a complete description would require a *univocal* coordination [*e i n d e u t i g e Zuordnung*] of ψ_2 with the physical state of point 2.” [*loc. cit.*].

Einstein then rules out an ensemble interpretation of the ψ_2 function “in Born's sense”, apparently interpreting the latter in a strictly statistical, i.e. not probabilistic (not describing one individual particle), way: the ψ_2 function would then be “coordinated [*zuordnet*], not to the state of an individual system, but only to a certain ensemble-state [*Zustands-Ensemble*] of material points 2. But one then just admits that ψ_2 does not describe the totality [*Gesamtheit*] of what ‘really’ pertains to the part system [*Teilungssytem*] 2, but only what we know from it in this particular case.” [*loc. cit.*]. Note, *en passant*, the quite strong realism of Einstein's conception: there is a “real” physical state of affairs pertaining to subsystem 2, independently of any knowledge we might have of it, and we should be able to “describe” this state of affairs in its entirety (this point is further underlined in the following paragraph, where Einstein rejects the opinion according to which “a more accurate description [*genauere Beschreibung*] would be inadequate”, because it would mean “that there would indeed be no *complete* lawful connections [*Verknüpfungen*] for the connection of the really existing [*des wirklich Seienden*]”). Finally, Einstein recommends, for solving the “dilemma” he has just described (of the incompatibility between completeness on the one hand, and separability and local causality on the other[8]), a research avenue “through a description which is much closer to the ‘classical’ [description]”, i.e. “from the point of view of the ‘classical field theory’ ” (in Cassirer, 2009, 160).

Before turning to Cassirer's potential reception of this exposition, let us formulate a few remarks. First, note that although the separability and local causality presuppositions are used together, the former is logically prior to the latter (one first needs separability to then make sense of local causality).

Second, the two horns of the dilemma sketched by Einstein (we can have either completeness or separability/local causality, but not both) are treated completely on a par: in particular, the requirement of completeness has no priority over that of separability/local causality. It is true that, in the EPR paper itself completeness is put to the fore (starting with the title of the paper). But separability/local causality act in it as fundamental *presuppositions,* without which the entire argument collapses. This point is nicely summarized by an introductory sentence of the article: “The second question [that of completeness] is thus easily answered, *as soon as we are able to decide what are the elements of the physical reality* [my italics]” (Einstein et al., 1935, 777). For the completeness requirement (“*every element of the physical reality must have a counterpart in the physical theory*”[9] [*loc. cit.*]) to make sense at all, we must in the first place define what we mean by an “element of reality”—thanks, of course, to the separability/local causality requirement. Thus, if any logical priority was to be made between the two requirements, separability/local causality would even be *prior* to completeness at any rate not posterior.

Finally, the importance of the separability/local causality requirement is confirmed by the fact that, in the subsequent, and more simple, versions that Einstein has given of the EPR argument (see again Fine, 2012, Section 1.3), while other unnecessary assumptions drop, this requirement always remains. It is true that Einstein has also produced an argument intended only to show the incompleteness of quantum theory while avoiding at the same time the separability/local causality assumptions (the “gunpowder” system), but this argument (which, as well as Schrödinger's “cat”, remains discussed today) only bears on a *macroscopic* system, for which, precisely, the separability assumption is already taken for granted.[10] On the contrary, non-separability with respect to *quantum* systems has been established as an experimental *fact* (for a review, see Paty, 1986), which forbids any completion of quantum theory by hidden variables (see Basdevant et al., 2002, chap. 14). Thus, while the question of completeness of quantum theory remains open, an argument of the EPR type on interacting quantum systems remains inapplicable, in so far as its premises are refuted in fact (at least in the case of photons, as established by Aspect's experiments of the late 70s/early 80s).

3. Cassirer's potential reception

What, then, must have been Cassirer's most probable reaction to Einstein's argument (if we put aside his admiration for him)? There are many elements, in his philosophy, which tend to show that he would have rejected it. All these elements, as we shall see, illustrate Cassirer's main epistemological thesis (present since his *Substanzbegriff und Funktionsbegriff* of 1910[11]), according to which it is the concept of *object* which is constantly redefined in the course of scientific progress from theory to theory:

> Thus we do not know “objects” [*die Gegenstände*] as if they were already independently determined and given as *objects*, but we know *objectively* [*gegenständlich*], by producing certain limitations [*Abgrenzungen schaffen*] and by fixing certain permanent elements and connections within the uniform flow of experience. The concept of the object in this sense constitutes no ultimate limit of knowledge. … The object marks the logical possession of knowledge, and not a dark beyond forever removed from knowledge. The “thing” is thus no longer something unknown, lying before us as a bare material, but is an expression of the form and manner of conceiving [*ein Ausdruck für die Form und den Modus des Begreifens selbst*]. What

[8] For Einstein's diverse formulations of this dilemma, see Fine (2012, Section 1.3).

[9] Note that, strictly speaking, this formulation only requires a surjection, as it were, from theory to reality (to each element of physical reality there must correspond *at least* one element of the theory, there must not be an element of

(*footnote continued*)
physical reality not represented). The bijection requirement (there must be one, and *only one*, element of the theory representing an element of the reality) is in fact implicitly used later in the paper, when the authors state that “*it is possible to assign two different wave functions* […] *to the same reality* (the second system after the interaction with the first)” (Einstein et al., 1935, 779).

[10] Schrödinger's cat thought experiment features a *composite* system: the poison and the cat (macroscopic sub-system) and the unstable atom (microscopic sub-system). For the former, separability/local causality is taken for granted. In the case of Einstein's thought experiment there is only *one* macroscopic system, thus separability/local causality does not even come into question: it is an argument which has to do with the completeness requirement only. Here I am interested (since I am dealing with the EPR argument) in the *link* between both presuppositions (separability/local causality *and* completeness). However, I shall also argue (see Section 3.2) that Cassirer would probably not have subscribed to the completeness requirement even considered as such.

[11] Hereafter *S&F*.

metaphysics ascribes as a property to things in themselves now proves to be a necessary moment in the process of objectification [*Objektivierung*]. In this connection the peculiar changeableness is explained, that is manifest in the content of scientific concepts of objects. According as the *function* of objectivity, which is unitary in its purpose and nature, is realized in different empirical material, there arise different concepts of physical reality; yet these latter only represent different stages in the fulfillment of the same fundamental demand. Merely this demand is unchanging, not the means by which it is satisfied. (Cassirer, [1921, 1936] 1957, 286–287, translation adapted from Cassirer, [1936] 1956, 137–138).

Let us now review these elements to more detail.

3.1. Separability and local causality

Speaking about the relationship between the concepts of "whole" and "part" in quantum theory, Cassirer writes:

From the very beginning [the quantum theory] had to desist from defining the whole as the "sum" of its parts; it explains that it is more than such an additional unity [*summenhafte Einheit*]. A system consisting of two electrons determines, from the point of view of quantum mechanics, the state of these two electrons; but the reverse does not follow. A knowledge of the states of the two parts does not determine the state of the total system, and a derivation of the latter from the former is out of the question.[12] *The question how, within a given whole, the singularization* [*Besonderung*] *may be accomplished and how we must differentiate and* "*individualize*" ["*individualisieren*"] *a certain ensemble* [*Inbegriff*] *accordingly always constitutes a difficult problem for quantum theory*. The ordinary method of counting, which presupposes that it is known from the beginning what is to constitute one thing and what two or more things, is here insufficient. *Individual things* [*Einzeldinge*] *are not delimited from each other* [*grenzen sich gegeneinander ab*]*in as simple a manner as in the sensuous-spatial intuition; rather, complicated theoretical considerations are always required in order to determine precisely what is to be treated as an individual, what is to be counted as a "one"*. [...][13] Here also we see clearly that *the determination of the individual, of that which truly figures as* "*one*" *being, is not the* "*terminus a quo*", *but always only the* "*terminus ad quem*" *for quantum theory - a result of the theory which cannot be anticipated dogmatically, from some* "*immediate intuition*". (my italics, Cassirer, [1921, 1936] 1957, 344–345, translation adapted from Cassirer, [1936] 1956, 187).

Although Cassirer does not here explicitly mention the EPR argument, the common point to these different considerations is the reliance on the quantum formalism for determining what is to be counted as "one", i.e. what is to be defined as an object, and the concomitant defiance on any spatial-sensuous intuition for doing this. It is thus likely that Cassirer would have rejected the separability and local causality presuppositions (based on a classical, field-like, conception of space) as a starting point for doing so. Indeed, such a position fits nicely in Cassirer's general transcendental conception which uses the current conditions of (theoretical or experimental[14]) *accessibility* of the object for *defining* the new object of a theory (here, quantum theory), without trying to think a "thing in itself" on the basis of previous (here, classical field-theoretical) presuppositions. To put it differently, we might say that Cassirer "contents himself" with the theory (which, at that time, was rather considered as a mere formalism) at disposal (as *constitutive* of its objects), without looking for a "super-theory" which would better fit some presuppositions about physical reality (here, of course, I have Einstein in mind). This is what Cassirer calls his "functional" conception of knowledge, developed since *S&F*, and which he takes to have been confirmed by the recent developments of quantum theory in *D&I*. It is worth quoting it at length, as it represents the foundation of Cassirer's epistemology:

The concept of law is now regarded as prior to that of object, whereas it used to be posterior and subordinate to it. In the substantialistic conception there used to be a definitely determined being, which bore certain constant properties and which entered, with other beings, into definite relations expressible by laws of nature. In the functional viewpoint, by contrast, this being constitutes no longer the self-evident starting point but the final goal and end of consideration: the "*terminus a quo*" has become a "*terminus ad quem*". We no longer have a being subsisting by itself, absolutely determined [*an sich bestehendes, absolut-determiniertes Sein*], from which we can immediately read off [*ablesen*] the laws and to which we can "attach" them as their attributes. What in fact constitutes the content of our empirical knowledge is rather the totality of observations which we group together in definite orders and which, in accordance with this order, we can represent by theoretical concepts of law. The extent of the dominance of these concepts marks the extent of our objective knowledge. There is "objectivity", or objective "reality", only because and insofar as there is lawfulness [*Gesetzlichkeit*] - not vice versa. *Thus it follows that we cannot speak of a physical* "*being*" *except under the conditions of physical knowledge - both the general conditions and those particular ones which hold for their observation and measurement*. [...] The "being" of physics, its empirical object, is of course never definitely given [*fertig-gegeben*], because it is never ultimately determined [*zu Ende bestimmt*]; but on the other hand it does no longer threaten us as a mysterious absolute whose last grounds we could not penetrate. *For the property of its empirical and theoretical determinability* [*Bestimmbarkeit*] *is now incorporated* [*aufgenommen*] *in its definition; it constitutes* [*konstituiert*] *the physical being, instead of merely expressing an accidental and unique feature of it*. We do

[12] Cassirer here refers to Weyl (1932, 92), who shows there that "*conditions which insure a maximum of homogeneity within* [a compounded system] **c** [made up of two sub-systems **a** and **b**] *need not require a maximum in this respect within the partial system* **a**": in other words the global system can be in a pure state (describable by a state vector) whereas the sub-systems need *not* be in pure states, but can be statistical aggregates. Furthermore, Weyl states that "*if the state of* **a** *and the state of* **b** *are known, the state of* **c** *is in general not uniquely specified*" (which he translates as the view that, in quantum theory, "*the whole is greater than the sum of its parts*": a "philosophical creed", as he calls it, endorsed by Cassirer in his citation). This, in modern terms (of density operators, see e.g. Basdevant et al., 2002, appendix D, especially pp. 452–454), means that the density operator $\hat{\rho}_C$ of the global quantum system is not, in general, factorized, and is different from the tensor product of the density operators of each sub-system $\hat{\rho}_A \otimes \hat{\rho}_B$. Now although Weyl here does not, of course, mention the EPR argument (the German, 2nd edition, cited here by Cassirer, having been published in 1931), he makes use, in his argument, of the tensor product structure which is at the basis of the EPR argument.

[13] Here Cassirer makes a brief reference to classical and quantum (Fermi–Dirac and Bose–Einstein) statistics, quoting *Jordan's Statistische Mechanik auf quantentheoretischer Grundlage* of 1933.

[14] Although Cassirer is usually much more theory-minded, he does evoke, especially in *D&I*, some experimental conditions of possibility of the object. For example, in the passage just quoted, he writes (apparently referring to the indistinguishability of identical quantum particles) that "certain elements which, according to the former [classical statistical] interpretation, were considered as separate [*gesondert*] must now be taken and counted as one, because it developed that *they could not be differentiated with our theoretical and experimental means*" [my italics, Cassirer ([1921, 1936] 1957, 344–345), translation adapted from (Cassirer, [1936] 1956, 187)].

> not simply read off the laws "from the objects", rather we condense [*verdichten*] into laws and thus objective statements the empirical data available through observation and measurement, and *apart from these there is for us no other objective reality to be investigated or sought after*. (my italics, Cassirer, [1921, 1936] 1957, pp. 278–279, translation adapted from Cassirer, [1936] 1956, pp. 131–132).

Here, as in the passage quoted at the beginning of Section 3, we are clearly at odds with Einstein's stronger realism, which permeates his letter to Cassirer. What I mean here is that although Cassirer, of course, is a "realist" in the broader meaning of this term (i.e. he does not reject the idea of an independent reality), he acknowledges the limits of the human mind in its theorizing activity (in its superimposing theoretical structures over the structure of reality, which will always remain partially unknown to us) whereas Einstein does not—thus, Einstein wants to have a "complete" representation of reality, as it "really" is (independently of us knowing it), as we have seen in Section 2. I shall return to this issue at the end of Section 3.2.3.

3.2. Completeness

If we now switch to the completeness requirement in itself (apart from the spatial presuppositions on which it is grounded in the EPR argument), i.e. the requirement for a univocal coordination between the elements of the theory and the elements of physical reality, what would have been Cassirer's position with respect to it?

Before *D&I,* Cassirer adheres explicitly to this requirement in several places. For example, in 1920 (perhaps influenced by Einstein's theory of relativity, the subject of his *ZER*[15]), he summarizes his conception of the *a priori* in the following way, in a letter to Moritz Schlick dated from October the 23rd: "I would consider as properly 'aprioric' [*apriorisch*] in the strict sense, only the thought of the 'unity of nature' i.e. the lawfulness [*Gesetzlichkeit*] of experience in general, or maybe [to put it] shorter: the 'univocality of coordination' [*Eindeutigkeit der Zuordnung*]: how now this thought is specified in particular principles and presuppositions: this, according to me, only comes from the progress of scientific experience, even if here also I do not recognize anywhere fixed schemes, but indeed constant fundamental motives [*Grundmotive*] of knowledge, i.e. of inquiring and questioning" (in Cassirer, 2009, 51). And Cassirer even adds thereafter that "the principle of univocality is to [him] more than a mere 'convention' or an 'inductive generalization': it is to [him] an expression of 'reason', of 'logos' itself".

However, the "univocality of coordination" Cassirer has in mind here (as well as in other places such as *S&F,* see e.g. Cassirer, 1910, 350–351,[16]) is not be the same as Einstein's. Indeed, it is a *regulative* requirement in the Kantian sense (i.e. it sets the goal of theorizing, without ever being fully realized in experience). Thus, Cassirer talks equivalently of the "lawfulness of experience in general" and of the "unity of nature"—a formulation clearly reminiscent of Kant's "systematic unity of nature", which is a purely regulative requirement of the systematic unity of laws.

In *D&I*, Cassirer does not mention the requirement of "univocality of coordination" (or completeness) as such, but only of "coordination", again in a regulative sense (not to be completely realized in experience), e.g. between different theoretical representations, as the following passage illustrates:

> [Physical thought] has to take into account the possibility that the passage to new realms of objects may demand profound changes, not only in the individual laws but in the general physical presuppositions and forms of thought. The demand for lawfulness [*Gesetzlichkeits-Forderung*] as such must be maintained at all times, but the demand, often made in the logic of classical physics, for 'uniformity' ['*Einförmigkeit*'] and 'similitude' ['*Gleichförmigkeit*'] in natural events must be abandoned. Modern physics finds itself forced to apply side by side different systems of concepts that are incapable of being reduced one to the other. But the *unity* [*Einheit*] of natural knowledge does not demand any such *identity* [*Einerleiheit*]. It is sufficient that the various systems can be put into definite *relation* with one another, that we can step from one to another in accordance with a definite *rule*. Such a rule has been established for the relation between 'classical' and quantum-theoretical concepts, in Niels Bohr's complementarity principle [which Cassirer apparently confuses here with the correspondence principle]. Here a kind of translation code is given us, which shows us in what way the different languages may be interconnected and used side by side. (Cassirer, [1921, 1936] 1957, 317–318, trans. adapt. from Cassirer, [1936] 1956, 165–166).

Such a regulative sense is also conferred, in *D&I,* to Cassirer's conception of the principle of causality, as Seidengart (1985, 402) rightfully notices.[17] Thus, we should not expect a subscription, from Cassirer's part, to a constitutive, EPR-type conception of univocal coordination. To better see this, let us now review Cassirer's conception of complementarity and of the Kantian idea of "complete determination".

3.2.1. Complementarity

Contrary to what Ryckman (2015, 83) says, there are strong elements in favor of Cassirer endorsing Bohr's principle of complementarity, although his customary cautiousness makes it difficult to clearly identify his position. Apart from the elements noted by Ryckman (2015, 82) (Margenau writing in his preface that "Cassirer mentions complementarity with approval" (in Cassirer, [1936] 1956, xx), Cassirer quoting Bohr's conception of the mutual incompatibility between causality and space-time description (Cassirer, [1936] 1956, 115), which are part of Cassirer's "narrative" of the historical development of quantum theory, Cassirer makes a few explicit statements describing his *own* philosophical position (in the former, his aim is rather to select some historical facts which illustrate, as it were, his general epistemological thesis[18]). The last paragraph of *D&I* is particularly striking in this respect. There, Cassirer makes "a conclusion of general philosophical significance":

> What the new physics has taught us is the fact that the change of "standpoint" which we have to make whenever we move from one dimension of meaning to another, whenever we exchange the "world" of natural science for that of ethics, art, etc. is not confined to this type of transition alone. *The manifold of "perspectives" which opens up before us has its methodological counterpart within physics itself. Modern physics had to abandon*

[15] Although this book was published in 1921, there is epistolary evidence that Cassirer had finished the manuscript (or at least a preliminary version of it) before the hereafter mentioned letter to Schlick of October 1920 (see the letters between Cassirer and Einstein of May and June 1920 in Cassirer, 2009, 44–47).

[16] I thank one of the anonymous reviewers for bringing this passage to my knowledge.

[17] It is not my aim here to analyze the main epistemological thesis of *D&I*, namely that "causality"—or, equivalently for Cassirer, "determinism"—, understood as a "demand for lawfulness", is preserved in quantum theory.

[18] Thus, when Cassirer quotes Bohr's position, it is to show that he does not dispense with the concept of causality altogether (an illustration of the main claim of *D&I*, which is to show that quantum theory is deterministic, in the sense of lawful).

the hope of exhaustively representing the whole of natural happening with one [Cassirer's italics] *firmly determined system of symbols. It finds itself faced with the necessity of applying different sorts of symbols, of schematic "explanations" to the same event; it has to describe one and the same being as a "particle" and as a "wave", and must not be deterred in this use by the fact that the* intuitive [Cassirer's italics] *combination of the two pictures proves impossible*. When the fundamental task of physical knowledge, when the connection of phenomena into firm lawful orders, demands the *duality* of description, the habits and demands of intuitive representation and "understanding" must be subordinated to this fundamental requirement. When, even in science, such a "superposition" of dissimilar aspects is necessary, it will be the more easily understandable that we shall meet such a superposition again as soon as we go outside its realm - as soon as we seek to realize the full concept of "reality", which relies on the cooperation of all functions of the spirit and can only be reached through all of them together. (my italics, Cassirer, [1921, 1936] 1957, 375–376, trans. adapt. from Cassirer, [1936] 1956, 212–213).

The first point to be made here is that Cassirer talks on his behalf, not on someone else's: the historical conclusion he makes about the development of quantum mechanics is his own. Second, the reference made here is of course to Cassirer's *Philosophy of symbolic forms* (Cassirer, 1923, 1925, 1929), whose fundamental principle, as stated here, is the need for a *multiplicity,* and, indeed, *complementarity*, of symbolic perspectives (i.e. ways of objectification) for properly, and fully, thinking reality. Thus, Cassirer sees complementarity in quantum physics (a well established "fact" [*Tatsache*], as he qualifies it) as a further vindication of the fundamental tenet of his *systematic* philosophy.

There are other statements illustrating Cassirer's endorsement of complementarity, on his own account. Thus, the new "state" concept of quantum mechanics

[…] takes on entirely different values, according to whether we describe it in one language [as a particle] or the other [as a wave], *and neither of these languages can claim to define it univocally and exhaustively* [my italics]. It presents itself differently to us according to the different standpoints from which we view it, and it is impossible ever to unite the different perspectives in *one* picture. The particle and the wave picture must be used side by side, without ever being able to be "congruent" ["*kongruieren*"], or to coincide, with each other. They superpose without ever uniting with, or penetrating, each other. (Cassirer, [1921, 1936] 1957, 348, trans. adapt. from Cassirer, [1936] 1956, 190).[19]

Furthermore, Cassirer's taking into account the *observational accessibility* of the object is an additional element in favor of complementarity. Thus, he remarks that the "determination" of the object of quantum physics never depends on the object alone, but also upon the type of observation performed, upon the means of observation chosen [*ibid.*]. Each measuring set-up provides a different "face", a different "picture" of the object (e.g. its particle or wave nature), and no single experiment can provide the totality of all possible aspects of the object at one time (for example, there is no experiment by means of which both the wave and particle nature of light can be demonstrated simultaneously) [*ibid.*]. Thus, and in conformity with Cassirer's Kantian stance, we cannot talk of a "'thing' in an absolute sense", i.e. without reference to the experimental circumstances of its observation [*ibid.*]—in contradistinction to Einstein who complains because (cf. Section 2) "ψ_2 does not describe the totality of what 'really' pertains to the part system 2, but only what we know from it in this particular case" (in Cassirer, 2009, 160).

At some point, Cassirer even seems to subscribe to the classical conception of the measuring apparatus (characteristic of the "orthodox" view of quantum mechanics). Indeed, calling for "'some Archimedean point', some basis threatened by no 'indetermination', if the construction of modern physics is to succeed", Cassirer cites, as apparently a legitimate option, Bohr's and Heisenberg's conception of the "observer's procedure as well as his measuring apparatus [which] have to be discussed according to the laws of classical physics, for otherwise there is no problem for physics to consider. Within the measuring apparatus all events are regarded as determined in the sense of classical theory; this provides the necessary presupposition for believing that what has happened can be univocally inferred from the result of measurement." (Cassirer, [1921, 1936] 1957, 265, trans. adapt. from Cassirer, [1936] 1956, 121). It is true, as Ryckman (2015, 83) remarks, that Cassirer also makes statements enjoining to abandon "the lost paradise of classical concepts" (Cassirer, [1921, 1936] 1957, 353), but here, he has in mind classical concepts—such as position and velocity—as applied to the quantum object, not the measuring apparatus.

Finally, Cassirer also sees the wave/particle duality as a true equilibrium "principle" of quantum mechanics, which "[…] avoids the dangers of pictorialism [*Bildlichkeit*] by forcing the pictures it uses to limit themselves and equilibrate each other" (Cassirer, [1921, 1936] 1957, 303–304, trans. adapt. from Cassirer, [1936] 1956, 151–152). Indeed, this principle never allows one picture alone to appear as the "exclusive representation [*Veranschaulichung*]" of the object observed, and the different (wave or particle) representations "neutralize each other as it were" [*ibid.*]. All that quantum theory teaches us is merely the rule according to which we can establish a purely "'*symbolic correspondence*'" (here we have again the regulative sense of "coordination" seen above) between the two pictures, in such a way that only both combined provide a satisfactory representation of the phenomena of atomic physics [*ibid.*]. Again we find here a typical feature of the *Philosophy of symbolic forms*: the constant endeavor to prevent one symbolic form of tending to "hegemony" over the others by reducing reality to itself (see e.g. Cassirer, [1923] 1956, 13).

3.2.2. *Cassirer's vs. Bohr's conception of complementarity*

It should be noted, however, that Cassirer does not fully endorse Bohr's conception of complementarity. It is not my aim here to compare their two conceptions (this would require to go into the detail of Cassirer's and Bohr's conceptions of "intuitive" and "symbolic" knowledge, and I refer for this to Pringe's (2014) analysis), save for a few remarks.

First, Pringe does not seem to realize the extent to which Cassirer adheres to Bohr's conception of complementarity. He states, for example, that "[…] in contradiction to Cassirer, Bohr maintains that the physical reference of quantum theory depends on *classical* descriptions of measurements results, which do provide us with spatio-temporal images" (Pringe, 2014, 421). But we have just seen that Cassirer also endorses a classical conception of the measuring apparatus like Bohr. However, contrary to Bohr, Cassirer does not consider that these classical measurement results provide us with *intuitive* spatio-temporal "images" or "pictures", because he conceives classical measurements as

[19] Here, strangely enough, Cassirer seems to confuse the wave/particle duality with the principle of superposition (as if the former was an illustration of the latter), since he continues by illustrating "this principle of superposition" with Dirac's exposure of the principle of superposition (in his *Principles of Quantum Mechanics*). In fact, the principle of superposition by itself says nothing of the wave/particle duality (in particular, it is used in the wave picture to account for interference phenomena). All it says is that any linear combination of wave functions is also a possible wave function (in mathematical terms, the family of wave functions of a given system forms a vector space).

already theoretically laden results—and even the concepts of space and time are not thing concepts but already measurement (and thus theoretically charged) concepts (Cassirer, [1921, 1936] 1957, 10).[20] Indeed, for Cassirer, the intuitive world remains outside physics: a measurement result is not an "immediate reproduction of sense data", but already presupposes "the most complex thought processes" (Cassirer, [1921, 1936] 1957, 164). Thus, although Cassirer has, like Bohr, a classical conception of measurements, the difference with Bohr is that for Cassirer these classical measurements are already no more intuitive, but *conceptual* (in conformity with Cassirer's philosophy of physics as exposed since *S&F*).

What is more, for Cassirer complementarity is also a way to define the quantum object in conformity with the higher regulative demand of systematic unity (or "univocality of coordination" in his understanding) suggested by the formalism of quantum theory, as we shall see. Thus it is not exact to maintain that "Cassirer's position leaves the systematic relationship between classical and quantum physics without a satisfactory explanation" (Pringe, 2014, 426), whereas Bohr's conception would ensure this systematic unity—precisely because here Cassirer follows Bohr's conception of complementarity (although he does not share his conception of classical physics as intuitive). In the same vein, Pringe (2014, 426 sq.) suggests "a transcendental conception of quantum objectivity" along Bohrian lines, in which:

1. the concept of a classical object is constitutive, enabling the constitution of empirical data as objective experimental results. Accordingly, it is directly exhibited in intuition;
2. the concept of a quantum object is regulative, guaranteeing the systematic unity of classically described complementary phenomena, which provide the concept of the quantum object with objective reality when they are indirectly exhibited in intuition, through symbolic analogies.

For Cassirer neither of these intuitive exhibitions (whether direct or indirect) of the object takes place, since he wants to dispense with any intuitive representation whatsoever. Even the concept of a classical object, as we have just seen, is not directly exhibited in intuition, but is empirically confirmed through measurement results which are already theoretical constructs. In the same way, the concept of the quantum object is *not* regulative for Cassirer as we shall see below: it is the systematic unity of laws (or the "univocality of coordination") which is regulative. Rather, the concept of the quantum object is directly *constitutive* through the new (experimental and theoretical) conditions of *accessibility* of the object.

Now which of these two conceptions (Bohr's or Cassirer's) should be considered best suited to quantum theory? According to Pringe (2014, 25), Bohr's conception of complementarity has the advantage of keeping both intuitiveness and unification in our physical knowledge, contrary to Cassirer's (which keeps only the latter). As we have seen, Bohr wants to keep spatio-temporal images of quantum objects and processes in order to exhibit them indirectly in intuition (in conformity with Kant's conception of symbolic knowledge), whereas Cassirer wants to dispense with any intuitive representation (taken in the Kantian, perceptual sense) whatsoever. Now I think that the adequacy, and the superiority, of Cassirer's conception over Bohr's for quantum theory is clear. To see this, let me distinguish, following Kant, between "empirical" and "pure" intuition.

First, with respect to empirical intuitions (which would directly correspond to empirical data obtained by classical measurements in a Bohrian conception), I think that the conception of classical objects being directly exhibited in intuition is hard to maintain, and that Cassirer's view (inspired by Helmholtz, Poincaré and Duhem) of any experimental fact being already theoretically laden and quite remote from everyday observation and language, and of immediate perceptual data being transformed into theoretically-informed measurement results and numbers, has rather become the "received view".

Second, with respect to the pure intuitions of space and time, we see that experiments of the EPR type precisely render the intuitive category of space (or space-time) inapplicable, and that if we want to keep the category of intuition, we should rather talk of a new "quantum intuition" (in this respect, see Paty, 1986). Indeed, it is impossible to represent an EPR type correlation in (relativistic) space-time, save by supposing a "super-luminic" causal influence contradicting the theory of special relativity.

To conclude, it seems that it is Cassirer's conception, rather than Bohr's, which enables to have "the best of both worlds", as Pringe (2014, 425) argues in favor of the latter (whose conception would ensure both intuitiveness and unification). Indeed, while Cassirer subscribes to Bohr's *idea* of complementarity (in the Kantian, regulative sense), he does not stick to his intuitive conception of classical objects. In particular, Cassirer conceives measurement results as a conceptual, and not an intuitive, product, what is more as an *open*, ongoing and never-ending process,[21] progressively ameliorated in the course of the successive theories (as every concept in his epistemology[22]). When one considers the epistemologically paradoxical character of the Copenhagen interpretation,[23] and the fact that it is rather the measurement process than the non-separability and non-local causality which might pose a potential problem for the completeness of quantum theory (see again Paty, 1986),[24] it would seem that it is Cassirer's open and non-intuitive conception of classical physics and of the measurement process, rather than Bohr's intuitive conception, which might do better justice to quantum theory and its potential evolution. In particular, Cassirer's conception of complementarity enables to conciliate classical physics and quantum physics *as well as* special relativity, something which Bohr's conception apparently does not. Thus, contrary to what Pringe (2014, 426) argues, it is Cassirer's conception rather than Bohr's which better ensures the systematic unity of physics, which, indeed, can only be achieved if science becomes "symbolic" in Cassirer's strict (Leibnizian, not Kantian) sense.

3.2.3. "Complete determination"

Another element of Cassirer's epistemology which is unfavorable to his endorsement of Einstein's completeness requirement is that the latter presupposes the Kantian "ideal of complete determination", against which Cassirer strongly argues:

> It seemed hitherto to be an axiom, not only of classical physics but of classical logic, that the state of a thing in a given moment is completely [*vollständig*] determined in every way and with respect to all possible predicates. This complete [*durchgehende*]

[20] This appears in *ZER*.

[21] In this respect, see particularly Schmitz-Rigal (2002).

[22] The characterization of Cassirer's general epistemology of science lies outside the scope of this article. It is sufficient for my purpose to say that Cassirer conceives scientific concepts as continuously and progressively improving towards an ideal (regulative) limit. Such a view is exposed in all his epistemological works (*S&F*, *ZER*, *D&I*).

[23] Conceiving the measuring apparatus in classical terms, and thus grounding quantum theory on one of its own limiting cases (since classical physics is supposed to be recovered as a limit to quantum theory).

[24] In particular, in the EPR case, as long as one has not performed any measurement, one might say that there is a "pacific coexistence" between quantum theory and special relativity theory (Redhead quoted by Paty, 1986, 86).

> determination was considered so certain that it was often actually used as a *definition* of what we are to understand by the 'reality of a thing'. […][25] It was particularly the spatio-temporal determination which since early times was considered as the true criterion of the 'existence' of an empirical object. (Cassirer, [1921, 1936] 1957, 347–348, trans. adapt. from Cassirer, [1936] 1956, 189–190).

In quantum mechanics, by contrast,

> […] we can no longer define existence as something completely and thoroughly determined [*ein vollständig und durchgängig Bestimmtes*]. The 'state' of a physical system no longer exhibits, according to the language of quantum theory, the same form of spatiotemporal connection [*Bindung*] which it possessed in classical mechanics. In the latter, all the individual elements could be isolated from each other; each particular being was, in a given instant of time, referred to a fully determinate point of space, and 'adhered' to it exclusively. Quantum mechanics, on the other hand, demands that we abandon this conception. [*ibid.*].

Cassirer makes these remarks in connection with Heisenberg's relations, which, indeed, make it impossible to define a spatio-temporal trajectory for a quantum particle. In this respect, Cassirer asks rhetorically if there is any sense in ascribing to electrons, whose path we can no longer follow, a "definite, strictly determined 'existence' [*definitives, streng-bestimmtes 'Dasein'*], which, however, is only incompletely 'accessible' [*unvollkommen 'zugänglich'*] to us", and urges "to take the opposite path", i.e. to "use the conditions of the possibility of experience, i.e. the conditions of 'accessibility' [*'Zugänglichkeit'*], as conditions of the *objects* of experience" (Cassirer, [1921, 1936] 1957, 334). This, of course, is nothing but a modern reformulation of the Kantian injunction to use "the conditions of possibility of experience as conditions of possibility of the objects of experience" (see e.g. Kant, 1781, A158/1787, B197). If we adhere to this epistemological programme, "then there are no more empirical objects that in principle can be designated as utterly inaccessible; and there may be classes of presumed objects which we must exclude from the domain of empirical existence because it is shown that with the empirical and theoretical means of knowledge at our disposal, they are not accessible or determinable" (Cassirer, *ibid.*). Again we think to Kant, for whom "the objects of experience are *never* given *in themselves*, but only in experience, out of which they have absolutely no existence" (Kant, 1781, A492/1787, B521).

Thus, the non-locality of quantum particles is here used by Cassirer to question their very *individuality*. In conformity with Cassirer's general epistemological thesis, what has to be re-conceptualized with the advent of quantum mechanics is not the category of causality, but that of substance and its related properties. In particular, the category of *space* may have to be abandoned, and a quantum particle does not have to be determined in this respect: a move which, contrary to Einstein, does not seem to be a problem at all for Cassirer. Thus, a concept such as that of the "material point" is a historical concept, which might have to be "reoriented" if the progress of scientific theorizing requires it, and in particular if it does not account for experimental data (Cassirer, [1921, 1936] 1957, 356). This concept, as any other theoretical concept of physics, " […] can never be understood as a copy of a physical object; it is a 'form', whose meaning and content consists of its theoretical performance, of its ability to lead to simple and strict laws of phenomena. *Every such form has its definite limitation; we must count on the possibility that areas of experience will turn up that it can no longer completely cover and express.*" (my italics, *ibid.*, trans. adapt. from Cassirer, [1936] 1956, 196). Here we find again the complementarity idea of the philosophy of symbolic forms, according to which no symbolic representation alone can, as it were, exhaust reality, *completely* represent it, but can only express one aspect of it, which can neither be suppressed, nor reduced to others.

To sum up, Cassirer's transcendental position, *constitutive* of objects of knowledge (which consists in using the conditions of *accessibility* of experience as conditions constitutive of the objects of experience), clearly stands at the antipodes of Einstein's stronger realism, more *descriptive* of a self-subsistent reality: recall the above remarks (in Section 2) about Einstein's realism, which requires that there is a fully determined state of affairs going on in sub-system 2, to be completely described independently of our potential cognizance of it. On the contrary, Cassirer would probably have considered "a more accurate description" as "inadequate", indeed (contrary to what Einstein calls for), precisely because "there would indeed be no *complete* lawful connections for the connection of the really existing": for Cassirer, physical theorizing works the other way round. It is not the substance (the "really existing") which comes first, and which then has to be lawfully connected: on the contrary the laws *define* what has to be counted as an object, and it doesn't matter whether the object is not spatially defined. Given that it is rather the measurement process—and thus our *gaining knowledge* of the physical situation at the remote point[26]—which might be the point at issue in the EPR argument (see the end of Section 3.2.2), it would seem that Cassirer's conception represents, again, the best option.

4. Conclusion

To conclude, Cassirer's philosophy might enable to "escape" the EPR dilemma sketched above, and which we might summarize as the incompatibility between separability/local causality (proposition *A*) and completeness (proposition *B*): we can have one of them, but not both. In formal terms: $A \Rightarrow \neg B$, or, equivalently, $B \Rightarrow \neg A$. As we have seen, Cassirer would have subscribed to none of the premises: neither *A* (separability/local causality), nor *B* (completeness) thus escaping, as it were, the EPR dilemma. Given the ongoing controversy surrounding the very existence of this dilemma (see Fine's (2004, Section 3.2) conclusion[27]), it might appear as a very reasonable option. Thus, although Cassirer's philosophy does not, to put it in Kantian terms, have any "positive utility" (because it does not lead to *new* physical knowledge), it does have a "negative utility" (criticizing already existing physical knowledge): following Kant's "transcendental method" in its

[25] Here Cassirer cites Kant's *Critique of Pure Reason*, where "'reality' and 'complete determination' appear as interchangeable concepts" [*loc. cit.*]. Let us not forget, however, that for Kant complete determination is an "idea" of pure reason (the concept of a single object completely determined by this sole idea being an "ideal"): "Complete determination is thus a concept which we can never present in concreto according to its totality, and it is thus grounded on an idea which has its siege in reason only, which prescribes to the understanding the rule of its complete usage" (Kant, 1781, A573/1787, B601). The principle of "determinability" states that, for any concept, of two contradictorily opposed predicates, only one can suit this concept; the principle of "complete determination" that, for any thing, "of *all possible* predicates of things, in so far as they are compared to their contraries, there must be one which suits [this thing]" [*ibid.*].

[26] Compare, again, to Einstein's complaint "that ψ_2 does not describe the totality [*Gesamtheit*] of what 'really' pertains to the part system [*Teilungssytem*] 2, but only what we know from it in this particular case" (in Cassirer, 2009) (see Section 2).

[27] In particular, there are elements going against both separability/local causality (Bell's theorem and its subsequent experimental confirmation) and completeness (Einstein's and Schrödinger's thought experiments).

analytic sense, Cassirer analyzes available scientific knowledge to identify, and criticize, its presuppositions—thus preventing any dogmatic metaphysics.

One might be tempted to object to Cassirer that the main epistemological thesis of *D&I*—namely that "determinism" or "causality", understood as a "demand for lawfulness", is preserved in quantum theory (because it does not, of course, dispense with lawfulness altogether)—is too general to be of any utility, reduced to the definition of physics itself, as it were. As Max von Laue puts it in a letter to Cassirer from March 26, 1937, "that the [quantum] theory still establishes laws is of little consolation; for what should it do otherwise?" (in Cassirer, 2009, 169). However, as I hope to have shown here, Cassirer's philosophy does have some (negative) utility: although his regulative demand for lawfulness might be considered as already belonging to the basic presuppositions of any reasonable physicist, it can favor the transition from one paradigm to the next[28] something the professional physicists themselves are not always willing to do, as we have briefly seen with Einstein. This has to do with the fact that this *regulative* principle (of systematic unity of laws) is further developed into *constitutive* principles based on the new experimental and theoretical conditions of accessibility of the quantum object, as we have seen.[29]

Finally, it must be added that Cassirer's *systematic* philosophy (his so-called "philosophy of symbolic forms" (Cassirer, 1923, 1925, 1929), might also have a "negative"—more exactly, an *anti-reductionistic*—utility for physics as a discipline, by preventing it from physicalism (the explanation of the entire reality in terms of physics)—as, in particular, the last chapter of *D&I* suggests. Such a retreat of philosophy at the borders of physics would be perfectly consistent with, and even naturally extend, the spirit of Cassirer's systematic philosophy (in which philosophy articulates each symbolic form without finding its objectivity from the inside). But this discussion must definitely be left for another occasion.

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[28] More exactly, it facilitates the abandonment of the old paradigm, without suggesting the new one.

[29] Cassirer's conception of the *a priori*, which I claim (*contra* Ryckman, 2015, 75 sq.; Friedman, 2001, 66) to have *both* a constitutive and regulative dimension, lies outside the scope of this article, and shall be treated in a future publication (Stamenkovic, 2016). In particular, contrary to what Seidengart (1985, 408) argues, I claim there that Cassirer fully grasps the constitutive nature of the Heisenberg relations for the quantum object. I also claim that this intertwining of these two (constitutive and regulative) dimensions is a consequence of the disappearance of the faculty of intuition in Cassirer's conception.