A WEAK QUANTUM-LIKE INDETERMINACY PRINCIPLE IN LOGIC

©Laureano Luna Cabañero
laureanoluna@yahoo.es

ABSTRACT

We resort to a logical phenomenon related to paradoxes and possibly to other logical facts, like limitation theorems and transfinite set theory, to shed light upon the meaning of Heisenberg's Indeterminacy Principle. Our aim is to show how *critical realism* as opposed to *naïve realism* might be consistent with this principle and its empirical and theoretical consequences.

Call *(1)* the sentence-token "(1) expresses no true proposition". (1) has no truth value, so it describes no state-of-affairs. We partly state this by means of the sentence-token *(2)* which says "(1) expresses no true proposition". (2) describes an actual state-of-affairs and is true. This is possible only because (1) and (2) are uttered in *different logical contexts.* Since (2) is based upon a previous assessment of (1), we say that (2) stands in a *logically posterior instant.* There is a state-of-affairs that is an *available* state-of-affairs in the logical instant to which (2) belongs but is not *yet* such in the logical instant in which (1) stands. Only the introduction of this kind of *logical temporality* makes the set of *available* states-of-affairs relative to the logical context, thereby rendering possible the solution to the paradox. This reveals that some logical objects are distributed along some *logical temporality.*

The reason of this relativity resides in a fact that can be couched in the terms of Husserl's phenomenology: *no intentional act can be contained in its own intentional object.* For the thinker who thinks that *p,* his being thinking that *p* is no possible intentional object and hence no possible state-of-affairs, even if it is so for any thinker that stands in a logically posterior instant. Thus, there is in logic an indeterminacy phenomenon, ultimately due to some *principle of no intentional self-reference* (*PNS*). This indeterminacy is, however, not absolute but relative to the logical contexts in which thinkers stand.

We argue that the Indeterminacy Principle in physics stems from a situation akin to that of logical paradoxes and that consequently it is relative to the observer's cognitive context. From the standpoint of a broad-sense *critical realism* (whose keystone is the distinction between *objective reality* and its *phenomenal appearance*) indeterminacy is only pertinent to the general way in which phenomena have to appear to certain observers, so that it implies nothing about objective reality itself. This is what we call *a weak indeterminacy principle.*

It is often assured that the experiments revealing violations of Bell's inequalities force us to renounce at least one of these two tenets: *realism, localism.* We argue that the reasoning only holds if reality could be translated without holes into its phenomenal appearance and this cannot be the case in presence of PNS. So critical realism together with PNS could make those tenets consistent with the known empirical or mathematical outcomes. In conclusion, it is suggested that an appropriate distinction between reality and phenomena, along with PNS, could turn quantum oddities more intuitive as well as compatible with critical realism. So, our main contribution could be the proposal of a reason why objective reality could not be completely reproduced in its translation into phenomenal appearance. This might in turn be of interest in the field of logic.

I. Assume that Heisenberg's Indeterminacy Principle only asserts we cannot simultaneously measure with arbitrary accuracy a particle's momentum and position; then the principle refers to our possible knowledge and it is what I shall call a *weak indeterminacy principle.* Assume, on the contrary, it asserts that a particle cannot have objective momentum and position at the same time. Then it refers to the particle itself and it is what I shall call a *strong indeterminacy principle.*

Let's now assume that Quantum Mechanics is correct and let's assume locality and usual logical induction as well. Then there exist some results that seem to force us to

accept that a particle's position and momentum (or all of a particle's spin-vector components, or all photons' polarization angles, etc.) cannot possess objective (measurement-independent) values at a time. Some experimental outcomes as the violations of Bell's inequalities (Aspect, Grangier, Roger 1982) seem to show almost exactly this. We will come back to this later.

On the other hand, trying to keep realism and Quantum Mechanics by rejecting locality or logical induction entails serious scientific and philosophical problems.

This situation suggests we lack any solid basis to believe the properties of a particle to exist with independence of our measurements of them; they rather look like coming into existence only when they are observed. So they seem to possess no objective existence whatsoever outside our minds and our knowledge.

Thus a case can be made for metaphysical anti-realism out of Heisenberg's principle.

Nevertheless, my claim will be that we can render realism consistent with locality and Quantum Mechanics with the help of two resources:

First: the distinction between *naïve* and *critical* realism; the adequate distinction has not always been observed in the physical discussions.

Second: what I call *a weak quantum-like indeterminacy principle in logic.*

II. I address now the first issue. I define *critical* realism, as opposed to *naïve*, as the claim that our sensible representations or *phenomena* are not themselves objective beings but that they do represent objective beings and their objective properties. For critical realism a perceived particle is the correlative of a part of objective reality and the particle's properties are the correlatives of some properties of that part of reality.

Whether the relation between phenomenal and non phenomenal properties is a strict isomorfism is a matter of discussion. I will accept the suggestion of Einstein, Podolsky and Rosen in the famous EPR paper (Einstein, Podolsky, Rosen 1935, p. 777):

If, without in any way disturbing a system, we can predict with certainty (i.e. with probability equal to unity) the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity.

In that context I understand *physical reality* as *objective* or *non phenomenal physical reality*, even though this remains ambiguous in the original paper. Although the claim I endorse is a strong one, I think we can get away with it.

Since objective reality cannot be indetermined, the momentum and position (or the spin vector components, or the photon's polarization angle, etc.) of each particle must exist at any time, *but only in the precise sense that their objective correlatives always exist.* In this sense they are at any moment objective states-of-affairs. Note I am not pretending that position and momentum are always definite but that their correlatives in objective reality are. As I have said, Einstein, Podolsky and Rosen did not quite observe this distinction: from the viewpoint of critical realism they should have clarified what they meant by *physical reality*, whether some *phenomenal* or some *non phenomenal*

reality. In the rest of the paper I will always use *reality* for *non phenomenal* or *objective reality.*

From the point of view of critical realism, as defined, what Quantum Mechanics shows is not that Einstein, Podolsky and Rosen were wrong as regards objective reality but that there exist some elements of objective reality (some objective states-of-affairs) that cannot be always translated *without loss* or *fuzziness* (*Unschärfe*) into our phenomenal representations. Since objective reality cannot be indeterminate but some of its states-of-affairs do become *fuzzy* or *erased* when translated into phenomenal appearances, it seems we have to posit the existence of what we could metaphorically call a *fuzziness injector* or *state-of-affairs eraser* standing between objective reality and its phenomenal appearance. So, it seems we have something lost in translation, so that the relation between objective reality and phenomenal appearance is not always an isomorphism. The Indeterminacy Principle should be understood as referring to the gaps in that translation and not to reality itself. The principle would only limit that which can be a state-of-affairs in the phenomenal appearance and not in reality itself; it would only limit our possible empirical knowledge of reality. Therefore it should be considered a weak indeterminacy principle.

The idea that the Indeterminacy Principle is to be applied to the phenomena as emerging from the confluence of reality and observation is old (see e.g. Heisenberg 1958a, 1958b). Consider, for instance, Heisenberg's famous words (Heisenberg 1958b, p. 75):

Natural science does not simply describe and explain nature; it is a part of the interplay between nature and ourselves (…)

And it is perhaps as old as the principle itself (Heisenberg 1927); consider the following translation from Heisenberg 1927 p. 185:

I think it is possible to formulate the emergence of the classical "trajectory" in the following concise way: the "trajectory" only emerges due to the fact that we observe it (...)

[My translation. The original text is: *Ich glaube, dass man die Entstehung der klassischen "Bahn" prägnant so formulieren kann: Die "Bahn" entsteht erst dadurch, dass wir sie beobachten (...)*]

This passage suggests the awareness of being speaking only about phenomena; nevertheless this possibility was not used by Heisenberg at that time to propose any kind of realism.

Anyway, this one thing has always remained unclear: *how can there be a loss of determinacy in the translation from reality to phenomena?* Which kind of thing is our metaphorical *state-of-affairs eraser?* Maybe I would contribute something new if I were able to suggest what this *eraser* could be and how it could cause an objective state-of-affairs to be no possible state-of-affairs for certain observers.

To try to explain this is why I have to resort to logic.

III. Consider the following version of the Strengthened Liar; let's call "(1)" the following sentence-token

(1) expresses no true proposition

Let us assume that (1) has been uttered before any assessment of a token of the same sentence-type has been performed; this will be an essential feature of (1). I will also assume a consistent bivalent logic within which all propositions or statements are either true or false but not both at the same time. Within this logic it is easily shown by *reductio* that (1) has no truth value and thence is no proposition or statement even though it is a *sentence* because of its linguistic form. Once we are aware of this, once we know (1) has no truth value, we are entitled to assert the following sentence-token:

(1) expresses no true proposition

which we will call "(2)".

Therefore (2) has to be true while (1), though identical word for word, has no truth value.

Considering that (1) and (2) are different sentence-tokens of the same sentence-type Haim Gaifman (Gaifman 1992, 2000) proposed already in 1992 that sentence-tokens, as located in a certain logical network or logical context, and not to the isolated sentence-type, could be the real truth value bearers. According to this, different tokens of a same sentence-type can have different logical values. In our example this looks rather odd because those tokens involve neither indexical terms nor any other linguistic ambiguities; indeed, the reference of "(1)" has been unambiguously fixed. Maybe it only becomes intuitive when we accept that utterances borrow their logical value from a certain *content* of an *intentional act* of thinking, namely, the propositional content the utterance objectifies and conveys. This interpretation of the meaning of utterances can be found in thinkers as distant as the Aristotelian Henry B. Veatch (Veatch 1952) and the analytical philosopher John Searle (Searle 1983). We will see that those two different tokens of the same expression-type do not correspond to equivalent thought contents. More concretely we will see that *sentence-token (1) is no objectivation of the content of any possible act of thinking* while sentence-token (2) is the objectivation of a consequence of this last thought, namely *that (1) is no objectivation of any possible thought.*

Frequently the propositional content of an act of thinking is simply identified with the *proposition.* In these terms we can say that different tokens of the same expression-type may differ in their capacity to express a proposition.

Propositions are frequently deemed to be the primary or immediate truth bearers; sentence-tokens may be regarded as mediate truth bearers as far as they express propositions. But the story is a bit more less simple; for consider that, strictly speaking, if you go up now and read again (1) or (2), what you read is no more the same sentence-token you read before. This is why it seems we should have a name for what all logically equivalent tokens of a same sentence-type have in common and share with no other objects, i. e. their capacity to express a particular proposition; we can call this the *sentence-case*. Extensionally defined, sentence-cases are the equivalence classes

determined in the set of all sentence-tokens by the relation *is a token of the same sentence-type and expresses the same proposition as.* Ordinary sentences have only one sentence-case that can be equated with the sentence itself, but, as we have seen, this is not always the case for sentences that have a paradoxical sentence-case. Thus sentence-cases, rather than sentence-tokens, should be the mediate truth value bearers. Nevertheless, here we will go on speaking of sentence-tokens, not of sentence-cases.

Let me freely use some concepts of Husserl's *phenomenology* and *phenomenological psychology* (Husserl 1900, 1901, 1913, 1925a, 1925b). It is a rather subtle question whether a proposition is the objectivation of an *intentional object* of a *thetic intentional act* or perhaps the proposition is the *expression* of the act itself, so that the proposition would also express *noetic* and not only *noematic* features of the act, namely, its thetic character. Since we shall not discuss this problem here, we will try to employ neutral terminology.

No one can really think *what I'm thinking in this very act of thinking is wrong;* but if sentence-token (1) were the objectivation of the content of an act of thinking, it would have to be the objectivation of the content an act of that kind, something like *the thought I'm expressing by means of this utterance is wrong.* Appealing again to phenomenological concepts, I suggest those acts are *phenomenologically* impossible; in general, it seems to me that *no intentional act can be its own intentional object or part of it*. I call this the *Principle of No Intentional Self-Reference* (*PNS* hereafter). "Self-reference" must be understood here exactly in the defined sense, for it can be shown that some kinds of linguistic self-reference are compatible with PNS, especially the kind of self-reference we find in the famous Gödel's sentence that, in its metamathematical interpretation, states its own formal unprovability (Gödel 1931). That kind of self-reference is consistent with PNS because it is no self-reference in a strict sense: Gödel's sentence, so interpreted, refers only to its own material form as a string of symbols and not to its own intentional content.

PNS is founded on the fact that any intentional object has to be previously given to its intentional act and cannot be created by the act itself. This is necessarily so in order to prevent circularity in the process of construction of our mental contents. Moreover it can easily be shown that a violation of PNS would imply the existence of an intentional act of actual infinite complexity, which seems obviously impossible. So PNS appears as an *essential and necessary* (or in phenomenological terms *eidetic*) feature of any intentional act.

Now if we examine the difference between sentence-token (1) and sentence-token (2) we realize that (2) can only be stated *after* an assessment of (1) has been accomplished. What entitles us to assert sentence-token (2) is just that we have noticed that sentence-token (1) lacks any truth value. Thus sentence-token (2) is in some sense *logically posterior* to sentence-token (1). (1) and (2) stand in different logical levels or, as I would rather say, different *logical instants.* Like Gaifman I believe that (1) and (2), although literally identical, are two different logical objects and I believe this is so because they must be assigned two different *logical instants*, one of them being *logically posterior* to the other. This reveals the existence of a kind of *logical temporality*. Let us call *T1* the *observer* or *thinker* that utters sentence-token (1) and *T2* the one that utters sentence-token (2); then I would say that T2 stands in a *logical instant posterior to that of T1.* So, the existence of a *logical temporality* is suggested not

as a chronological order in a strict sense but as a necessary order in the introduction of certain logical objects.

I think this *logical temporality*, whose introduction I propose, is in fact long since (partly and implicitly) adopted by working mathematical logicians, not only to avoid paradoxes, as in the iterative conception of sets and its *temporal metaphor* (namely, that elements must be *previous* to sets) but also in the various set-theoretical and proof-theoretical reflection principles.

However, we have not yet accounted for the Strengthened Liar. For after all sentence-token (1) seems to express an objective state-of-affairs (namely that (1) is not true) that has to be or not to be the case, according to the principle of excluded middle. So, after all sentence-token (1) should possess a truth value. To account for the paradox it must be shown that sentence-token (1) cannot have its own not being true as an objective state-of-affairs to state about.

We have indeed accepted that the logical value of (1) is an objective well-defined state-of-affairs for thinker T2. So the problem is: *how can it happen that it cannot be such for thinker T1? How can it happen that sentence-token (1) has no truth value even if it seems to describe a definite state-of-affairs?* In order to *account for* the fact that sentence-token (1) has no truth value (and not only in order to *prove* it) we must make intuitive that it describes no state-of-affairs at all.

I think that PNS can shed light on this. It seems a reasonable claim that whatever cannot be an intentional object for a particular intentional act cannot be an objective state-of-affairs for that act. Let *p* be a proposition; then while I'm thinking that *p*, I cannot think that I'm thinking that *p*, so the fact that I'm thinking that *p* is not an objective fact for me, although it is indeed an objective fact in some absolute sense. Consequently when I'm thinking that *p* I'm unable to state this very fact. I will only be able to do it in a *logically posterior instant*.

O*bserver* or *thinker T1,* that simply utters or recites sentence-token (1), is unable to have the truth value of sentence-token (1) as an objective state-of-affairs since, for it to be so, he should be able to grasp, in an act of uttering, the incorrectness of the very act of uttering he would be performing. As, according to PNS, no intentional act can grasp itself, there is no possible state-of-affairs for T1 to assert. Sentence-token (1) cannot have its own not being true as an objective state-of-affairs and this is why it cannot even express it.

Note that this could be a key to the solution of the paradox, for this could make more intuitive that sentence-token (1) cannot describe any state-of-affairs whatsoever.

Let's take another look at the existence of logical contexts in which some states-of-affairs cannot be such for some observers.

IV. A certain Epimenides gained time ago a world-wide reputation as inconsistent for the following two reasons. Not just because he wrote something like *Cretans always lie* but because at the same time he was a Cretan. As Arthur N. Prior pointed in his article *Epimenides the Cretan* (Prior 1958, p. 261) the paradoxical feature is here that Epimenides sentence seems to permit the *pure logical* deduction of an empirical fact,

namely, that there is something else and true asserted by some Cretan in some occasion, for if we accept that Epimenides sentence has a truth value, then we must infer it is false.

What was wrong with Epimenides sentence? This one thing: since the sentence meant to refer to the truth value of *all* statements of Cretans, if it had been a statement, it would have referred to its own truth value. But for Epimenides the truth value of his own utterance could not be an objective state-of-affairs, a situation to pass judgment on. According to PNS *the correctness or incorrectness of Epimenides thought could be no state-of-affairs for his very act of thinking.*

We could come to the agreement that it is not reasonable to read Epimenides sentence as referring to itself, because Epimenides could not intend it; then words like "always", "all" etc., expressing universal quantifiers, should receive a restricted interpretation in some contexts. We would have then no paradox. This is another way of dealing with the whole problem that would lead us to the same conclusions but that we will not undertake here.

Note that the logical value of Epimenides utterance is available to us as an objective state-of-affairs even if it was not so for Epimenides himself.

In this sense, Prior (Prior 1958, p. 265) comments in the mentioned article:

Thus what can be or not be the case, is not necessarily assertible by a given person, or a person in a given situation.

The fact that paradoxical sentences suffer from a reference gap, the fact that they seem unable to refer to what they appear to refer, can be approached from John Austin's theory of truth (Austin 1950). According to it, any statement *p,* in order to be true, has to refer, through some *demonstrative convention*s, to a state-of-affairs *S* in the world.

And Austin comments (Austin 1950, p. 121):

There is no reason why the world should not include the words, in every sense except the sense of the actual statement itself which on any particular occasion is being made about the world.

The truth value of Epimenides utterance is not in the world for the uttering Epimenides, and consequently Austin's condition is absent from Epimenides utterance as it was from sentence-token (1). As a consequence of PNS, there are no demonstrative conventions allowing an utterance to effectively refer to its own being false or true.

For this to be so it is necessary that Epimenides could not refer to his own utterance by means of the concept of "statement of a Cretan". As long as the referring power of a concept is nothing else than its extension, it is clear that the theory of logical temporality has to include a stratification proposal for the set theoretic comprehension scheme. Indeed that proposal could be said to be the cornerstone of the theory.

V. Now let's suppose Cretans can be found in only two states: sitting and standing. Suppose I am from Crete myself and that I am standing. Suppose I say: *standing*

Cretans always lie. To avoid paradox we must grant that I would have uttered no statement at all. But if, while standing, I utter the sentence *sitting Cretans always lie* no problem arises.

The point is that if I am a standing Cretan and I try to state about the statements of standing Cretans I could easily become a part of the object I'm trying to state about and consequently I could fall prey to PNS.

So, it seems that if I'm a Cretan and I'm trying to utter a statement, either the truth value of statements of standing Cretans or the truth value of statements of sitting Cretans can be an objective state-of-affairs for me, *but not both at a time.* And this limitation holds only for me and the rest of Cretans when intending to utter a statement, not for other humans or even for Cretans in other contexts. This is an analogue of Heisenberg's principle or even of Bohr's *complementarity principle*, but it is obviously relative to the *observer* or *thinker* and his context, and implies by no means that any of those truth values of statements of Cretans are objectively indeterminate. So here it is all about a *weak indeterminacy principle in logic.*

As we have seen when speaking of sentence-token (1) and sentence-token (2), the nature of the relativity of the available states-of-affairs is linked to the proposed logical temporality: *what is and what is not an available state-of-affairs depends on the logical instant in which the thinker stands; what in some logical instant is "not yet" an available state-of-affairs can become such in a logically posterior instant.*

Logical temporality presents itself as an order in the introduction of certain logical and mathematical objects that has to be observed to prevent circularity. And logical temporality (like chronological temporality) seems to be recurrent or inexhaustible: in some realms whenever we have objectified a logical or mathematical object we can in principle construct another object logically posterior to the first. For instance, whenever I have a sentence *p* I can in principle construct the logically posterior sentences "*p* is true" and "*p* is false". As already suggested, this could be related to the reflection principles or the axiom of the power set. This inexhaustibility might be suggested as the common root of the recurrence in limitation theorems and transfinite set theory, while paradox could be the punishment for the sin of trying to exhaust the inexhaustible: if we try to climb up to the top of the sky our language will get confused. I think the existence of a kinship between the Babel, the Cantor and the Gödel effects, between paradoxes, transfinite set theory and limitation theorems, remains hard to reject.

VI. Heisenberg's Indeterminacy Principle might be a consequence of PNS on the level of physical observation. I will put it the usual way: when we observe the world we cannot observe at the same time our observation of the world, so that, if this observation is itself a part of the world, then it has to contain a gap. The phenomena could display this gap in the way quantum physics predicts. For instance, if we are engaged in measuring a particle's momentum we will become a part of the state-of-affairs that includes its position, so that the latter will become fuzzy for us, and the particle will show up as a wave. So, PNS would act as a *state-of-affairs eraser* once more but now on the level of quantum observation.

But we must consider whether this interpretation is consistent with the available theoretical and empirical results.

D'Espagnat in *The Quantum Theory and Reality* (D'Espagnat 1979) tried to make clear to lay readers that the results of some experiments testing Bell's inequalities entailed that at least one of the following three premises had to be wrong:

1st. Realism, i. e. there exists a physical reality independent of the knowing subject.
2nd. Locality, i. e. there are no superluminal influences.
3rd. The usual logical induction.

These premises were said to entail Bell's inequalities, which were in turn disproved by some experiments.

This line of reasoning originates from the well-known works of Einstein, Podolsky and Rosen in 1935 and John Bell in 1964 (Bell 1964). This line of reasoning, I suggest, has a loophole for it does not correctly observe the distinction between reality and phenomena. Once this is corrected, we notice that in order to infer Bell's inequalities a fourth premise has to be added, namely:

4th. There is no *state-of-affairs eraser* between reality and its phenomenal appearance.

The fourth premise has to be added because such an *eraser* could account by itself for the phenomenal indefiniteness of some states-of-affairs and so for the violations of Bell's inequalities.

If PNS works as a *state-of-affairs eraser* at the phenomenal level, it contradicts this fourth premise. Therefore the previous three premises (realism, locality and logical induction) together with PNS could be consistent with the available experimental and theoretical results. If there is a veil that veils reality, as D'Espagnat once defended, (D'Espagnat 1991), that veil could be PNS.

Once we have correctly drawn the line between reality and phenomena, we cannot expect phenomena to violate the *eidetic principle PNS* whose physical consequence might be Heisenberg's law. So, if the possession of some property cannot be an objective state-of-affairs for us and this on the grounds of an essential phenomenological necessity, then every relevant empirical test or mathematical result should reveal that necessity: the property at issue must disappear from each empirical or mathematical outcome whenever PNS demands it. And this even if the corresponding property in exterior reality is still there. The point is that *the phenomenal world includes our unavoidable uncertainty as a trait of its general way of appearing.*

But this implies nothing regarding reality itself; it just shows the way phenomena have to appear to us; it concretely shows they must behave in a way consistent with our impossibility to fill in all gaps PNS causes in our knowledge. Bell's inequalities, their preservation or violation, can say nothing about non phenomenal reality.

VII. Nevertheless, the fact that on the phenomenal level certain properties cannot be entirely determinate has an implication we cannot ignore: the indeterminacy in our knowledge appears to be *insurmountable.* So, even if Quantum Mechanics might be no complete description of physical objective reality, it might be a complete description of physical phenomenal appearance.

In his famous contention with Bohr and Heisenberg, Einstein tended to believe that quantum theory was *incomplete* and therefore *not finally valid* (*endgültig*) since he thought it could be completed and improved, while his opponents held it was both complete and finally valid. I feel inclined to be very equitable here: Quantum Mechanics seems to me to be incomplete as regards reality itself (as Einstein argued, although he did not explicitly refer to non phenomenal reality) but also incompletable and hence probably *definitive* or *ultimately valid*, as Bohr and Heisenberg claimed. If PNS is an eidetic feature of our phenomenal knowledge, we will never find hidden variables capable to get around it.

VIII. To summarize, I would say that an adequate distinction between reality and phenomena along with the theory of logical temporality might account for quantum oddities without any need to relinquish the philosophical tenet of the existence of an objective reality.

REFERENCES

Aspect, A., Grangier, P., Roger, G. 1982. "Experimental Realization of Einstein-Podolsky-Rosen-Bohm Gedankenexperiment: A New Violation of Bell's Inequalities". *Physical Review Letters,* vol. 49, n. 2, pp.91-94.

Austin, J. L. 1950. "Truth" in *Philosophical Papers.* Oxford University Press, 1979, pp. 117-133.

Bell, J. S. 1964. "On the Einstein Podolsky Rosen Paradox". *Physics,* vol. 1, n. 3, pp. 195-200.

Bohr, N. 1928. "Das Quantenpostulat und die neuere Entwicklung der Atomistik". *Naturwissenschaften* 16, pp. 245-257.

Chapuis, A. and Gupta, A. (eds.). 2000. "Circularity, Definitions and Truth". *Indian Council of Philosophical Research.*

D'Espagnat, B. 1979. "The Quantum Theory and Reality". *Scientific American,* vol. 241, n. 5, pp. 128-140.

D'Espagnat, B. 1995. "Veiled Reality. An Analysis of Present-Day Quantum Mechanical Concepts". *Addison-Wesley.* Reading, MA.

Einstein, A., Podolsky, B., Rosen, N. 1935. "Can Quantum-mechanical Description of Physical Reality Be Considered Complete?" *Physical Review,* vol. 47, n. 10, pp. 777-780.

Gaifman, H. 1992. "Pointers to Truth". *The Journal of Philosophy,* 89, pp. 223-261.

Gaifman, H. 2000. "Pointers to Propositions". In Chapuis and Gupta 2000, pp. 79-121.

Gödel, K. 1931. "On Formally Undecidable Propositions of *Principia Mathematica* and Related Systems I". In Van Heijenoort 1967, pp. 596-616.

Heisenberg, W. 1927. “Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik”. *Zeitschrift für Physik*, 43, pp.172-198.

Heisenberg, W. 1958a. *Das Naturbild der heutigen Physik.* Rowohlt, Hamburg.

Heisenberg, W, 1958b. *Physics and Philosophy. The Revolution in Modern Science*. Allen and Unwin, London, 1959.

Husserl, E. 1900. *Logische Untersuchungen.* Erster Teil. Martinus Nijhoff, The Hague, 1975.

Husserl, E. 1901. *Logische Untersuchungen.* Zweiter Teil. Martinus Nijhoff, The Hague, 1984.

Husserl, E. 1913. *Ideen zu einer reinen Phänomenlogie und phänomenologischen Philosophie.* Martinus Nijhoff, The Hague, 1950.

Husserl, E. 1925a. “Phenomenology”. *Encyclopaedia Britannica.*

Husserl, E. 1925b. *Phänomenologische Psychologie.* Vorlesungen Sommersemester. 1925. Martinus Nijhoff, The Hague, 1968.

Prior, A. N. 1958. “Epimenides the Cretan”. *The Journal of Symbolic Logic,* vol. 23, n. 3, pp. 261-266.

Searle, J. 1983. *Intentionality: An Essay in the Philosophy of Mind.* Cambridge University Press.

Van Heijenoort, J. 1967. *From Frege to Gödel: A Source Book in Mathematical Logic 1879-1931.* Harvard University Press. Third printing 1976.

Veatch, H. B. 1952. *Intentional Logic: A Logic Based on Philosophical Realism.* Yale University Press, New Haven.