PHENOMENOLOGICAL SCIENTIFIC REALISM
Einstein, Husserl, and Neelamkavil

Ruth Castillo Ochoa

1. Unobservables and Theoretical Entities in Physics

There is no vacuous entity. Hence, there are Extension (parts), Change (action), and universals (ways of process / characteristics / qualities, and their conscious reflections: essences) in existents. All existents are processes in all their parts. Accordingly, at the end, I draw some important conclusions with respect to gravitation, space-time, Relativity Theory, etc., and about Causality.

Part 1 moves between 'theoretical terms' and 'unobservables' beyond positivism. After arguments in part 2 based on Edmund Husserl, we recognize in part 3 that real unobservables are partial unobservables, and 'theoretical terms' are representative linguistic mechanisms based on universals. Without these, theory has no significance, cannot yield relevant truths. If an unobservable is proved contradictory, it disappears from theory and is surpassed by more relevant ones. But space-time are epistemic theoretical terms. Extension-Change are the ontological ones. This has implications to physics, especially to General Relativity.

I begin with tentative definitions: Unproved entities are either 1) *Unobservables*: theoretically and empirically necessitated but difficult-to-observe 'processual existents', whose essence-imbued theoretical descriptions represent existent processes with their universals, or 2) *Theoretical entities*: merely theoretically necessitated universals (e.g., malleable, hard, heavy), their conglomerates (e.g., centrifugal force, potential energy), and laws – all assumed to be entities not representing existents but are either aspects or processes inevitably pertinent to them. Why are unobservables and theoretical entities problematic? They are similar, but the former need workable recognition-and-existence-criteria that are scientifically and philosophically justifiable.

1.1. Situating the Problem in Historical Prefigurations

Scientists construct unobservables as possible existents, from certain indicative manifestations, e.g., Leucippus' and Democritus' atoms, Newton's universal gravitation, Boscovich's (Boscovich 1763, 39, §9; McMullin 2002, 27) and Faraday's electric field, Einstein's four-dimensional space-time, etc. Gravity remains very much without direct ontological criteria. The history of scientific knowledge suggests that we have insufficient ontological achievement on the intelligibility of so-called "well-defined" theoretical constructs that account for (partially) unobservable processes possessing some scientific characteristics. Rational powers in science, in constant struggle against skepticism, are reassured to the extent that theoretical constructs are adjusted to the demands of understanding related phenomena and data. Hence the need of categorially necessary criteria for unobservables and theoretical entities.

Rather than looking for directly empirical findings (e.g., visible electromagnetic spectral lines), we seek to understand the phenomena in question (layers of 'giving-itself' – not the whole reality – of processes, resulting in layers of data) in ways determined through theoretical constructs. This necessitates that in science intelligibility admits of the participation of unobservables. Most probably some unobservables 'exist' (existent reals); and 'there are' universals that pertain to many existents (non-existent reals). The present work aims to yield two universal Categories for physics, functioning as criteria of determination of existence of unobservables and of the mere space-time reality of constructs pertinent to existents.

From the 17th century to the present, science has emphasized its experimental nature. No philosophical or scientific discipline questions the link between experience (observation, posing problems, experiments), hypotheses, and theory (systems of concepts explanatory of experience). The duality between experience and theory[1] reflects the relationship between thought and reality. In this order of ideas, questions arise: Given the existence of theoretical constructs what is the certainty of observation from within the formation of concepts, statement of problems, and formulation of hypotheses and theories? Does all observation require some prior universals and knowledge? Do directly denoting terms exist in everyday language and scientific theory? Do their meanings depend exclusively on sensory perception? Responding to these concerns leads to investigation into the possibly ultimate criteria of scientific observation by analyzing the conceptual but reality-imbued acquisition of the meaning of terms directly representing observable and unobservable objects. A distinction between the two terms is offered by Anjan Chakravartty:

[1] "Several authors (…) denounced that the theoretical / observational distinction supposed the confusion of two dichotomies, in some sense related, but different: the dichotomy between the observational and non-observational and the dichotomy between the theoretical and the non-theoretical." (Carman, 2016, 3) For a comprehensive review of the possible distinction between theory and observation in science, Olivé & Ransanz, 1989. (Own translation, wherever the original is in Spanish or Italian.)

> There are things that one can, under favourable circumstances, perceive with one's unaided senses. Let us call them "observables", though this is to privilege vision over the other senses for the sake of terminological convenience. Unobservables, then, are things one cannot perceive (…), and this category divides into two subcategories. Some unobservables are nonetheless detectable through the use of instruments with which one hopes to "extend" one's senses, and others are simply undetectable. These distinctions are important, because major controversies about how to interpret the claims of the sciences revolve around them. (Chakravartty, 2007, 4)

The problem of postulations and distinctions around unobservables has much been analyzed logical-semantically, focusing on the meaning of scientific terms and how to incorporate them into theories under appropriate languages. Similarly, taking into account the nature of perception-observation, unobservables have been investigated epistemologically. One often forgot that 1) qualities are not quality-words, and 2) existents are not existent-representing words. In both these, the above-mentioned kinds of unobservables and theoretical entities are active.

Through review and reconstruction of applications and theoretical trends addressing the problem of unobservables, a renewed vision of Edmund Husserl's notion of essence and its constitution is offered through intersubjectivity by G. J. Mastrobisi (2015, 2018), which I subsume under the physical-ontological categories, namely Extension-Change, of Raphael Neelamkavil (2018), showing Husserl's phenomenology as a complete methodological framework elucidating physical sciences. This result is then used to view the status of space-time and unobservables in Einstein's physics.

1.2. "Unobservable Terms" in 20th Century Positivist-Analytic Philosophy of Science

At the dawn of the 20th century, logical positivists addressed, under the empiricist vision, the problem of unobservables through the conception that knowledge begins with experience, experience being the unquestionable cornerstone justifying knowledge. For them, knowledge of 'the given' is possible only through the sensory experience of observation, direct or instrumental.

The problem of how unobservables (for them, mere theoretical terms!) such as electron, field, energy, gravitation, etc. acquire meaning was treated consistently through attempts to posit the existence of a basis constituted by what is given in immediate experience. Theoretical or unobservable terms acquire meaning based on the meanings of non-theoretical or observational terms. These terms appear in scientific theories as auxiliaries in the basic functions of theories, namely, explanation and prediction of observable phenomena. Hence, a task of philosophers of science is to analyze how observational (observables, unobservables) and non-observational terms (theoretical entities) are linked within theory.

Dudley Shapere codifies the attempts of logical empiricists to solve this problem in "The Problem of Theoretical Terms" (1964). He begins by exposing the solution offered by P. W. Bridgman's operationalism, whose central thesis is:

> We mean by any concept nothing more than a set of operations. The concept is synonymous with the corresponding set of operations. If the concept is physical, as in the case of length, such operations will be effective physical operations, that is, those by which length is measured; if the concept is mental, as in the case of mathematical continuity, the said operations will be mental, that is, those by which we establish whether a given aggregate of magnitudes is continuous. (Bridgman, 1985, 16)

Note the first line where he affirms: by any concept he means nothing more than a set of operations. Under this view, scientific concepts are defined and acquire meaning by "what one does with it, not by what he says about it." (Bridgman, 1985, 18). In this sense, the variation in our way of 'experiencing' and 'measuring' the world is in almost direct correspondence with changes in conceptual structuring, there being a link between 'experience' and the operational form in which we describe it.

According to Bridgman's postulation, concepts in science acquire meaning through experimental procedures by assigning them numerical values. (Bridgman 1985, 16) These ideas are made explicit by Bridgman from the concept of 'length' which he studies under contrast between the traditional operational mode (and therefore the conceptual structure of what is understood by length and its determination) and the form of 'measuring' longitude in Einstein's Special Relativity. Bridgman says:

> We can gain greater familiarity with the operationalist attitude toward concepts, and with some of its implications, by examining the concept of length (...) by extending a measuring stick over the object in such a way that one end coincides with one end of the object, we mark on the object the position of the other end of the rod, consequently we place the rod according to an extension in a straight line from its previous position until the first end coincides with the previous position of the second end of the rod, then we repeat this process as many times as we can and, finally, we call "object length" the total number of times the rod was applied. This procedure, apparently as simple, is excessively complicated in practice (…) *In principle*, the operations by which length is measured must be *singularly* specified (…) We do want to be able to measure the length of bodies in motion at high speeds (…) we must adopt another definition and other operations. (…) This is precisely what Einstein did. Since Einstein's operations were different from the operations mentioned above, their *"length" does not mean the same as our "length"* (Bridgman, 1985, 20-23)

Bridgman gives an account of the link between operations and concepts. However, later he states: "if the concept is physical, as in the case of length, such operations will be effective physical operations, that is, those by which length is measured; if

the concept is mental, as in the case of mathematical continuity, the said operations are mental." (Bridgman, 1985, 16) There is no clear definition of what he understands by 'operation'. He adds to the set of admitted operations those referred to as 'mental', obscuring what we must understand and accept as operation within the operationalist vision. This ambiguity is picked up by Shapere in his 1964 dissertation. Shapere asks: "What does Bridgman mean by 'operation'? (…) We think first of instrument manipulations; but (…) this is not enough to account for the significance of all scientific concepts: the operationalists had to admit varieties of non-instrumental operations." (Shapere, 1964, 51)

As it is, the vagueness around the meaning of 'operation' enables the inclusion of considerations that operationalism itself rejects. There is no distinction satisfying the difference between possible and impossible operations. Then arise different interpretations. Following Shapere, three interpretations can be synthesized: (1) understand the operation as 'technically possible' if it agrees with the prevailing theory, although the way to carry out the operation is unknown, (2) an operation is possible or impossible depending on whether it is permissible in terms of the prevailing scientific theory, and (3) an operation is possible if it is not logically self-contradictory. (Shapere, 1964, 52)

Each of these has difficulties that subject operationalism to divergences. The first and third interpretations establish a wide margin of what operationalism can admit as a possible or impossible operation, while the second restricts the progress of science by allowing the incorporation of crazy proposals. Shapere summarizes the divergences:

> (1) A proposed operation may be technically possible, in the sense that it is possible according to prevailing theory, but no way is known to carry out the operation. But this clearly would not do justice to what the operationalist has in mind. (…) (2) The relevant sense may then be that of the theoretical possibility or impossibility: an operation is possible or impossible if it is permissible in terms of the prevailing scientific theory (independently of the 'purely technical problem' of whether we can carry it out). Thus, although it is not technically possible (yet) to travel to distant stars, in terms of the laws of physics now known, this possibility is not excluded; interstellar travel is "theoretically" possible. But if this sense of 'possible' were taken (…) a serious restriction would be placed on the capacity for progress of science according to operationalist criteria, since speculation in terms of "operations" not supported by the prevailing theories would not only be crossed out false, but would be considered a point of gibberish. (3) Nor is it useful to interpret 'possible' in terms of "what is not logically self-contradictory" since the result would be too broad. (Shapere, 1964, 51-52)

From this point of view, operationalism requires defining and clarifying what it understands as 'possible operation', that is, to understand 'possible' in an intermediate sense between 'possible in terms of the prevailing laws' and 'logically not self-contradictory'. Overcoming this difficulty implies overcoming another challenge: the demarcation between theory and experience.

Many are the so-called successful applications in philosophy in this regard. However, the distinction is still fuzzy and involves an open problem in philosophy of science. Is it possible to recognize a point of elucidation that allows overcoming the difficulty of establishing an adequate demarcation? In Bridgman's operational proposal, difficulties are detectable that make the purpose inaccessible. Is it possible through another philosophical perspective? At the start of the 1920s a group of scientist-philosophers, the Vienna Circle, emerged. They and their counterparts elsewhere founded 20th century's logical positivism. They studied some fundamental philosophical aspects inherent in science, among them also the distinction between theory and experience.

The central doctrine of logical positivism is the verificationist (and falsificationist) theory of meaning. A statement about a fact would only make sense if there were some empirical procedures supported by experimental observation, capable of verification (and falsification). For them, each term defined in reference to a set of sensory data was an 'explicit definition'. Thus, every 'meaningful' statement must refer to empirically verifiable facts: if these situations occur, the statement is verified; otherwise, false. On the other hand, an empirically non-verifiable statement is a 'nonsense' statement constructed without respecting the rules of syntax. It cannot be true or false, since it is a poorly constructed statement.

There is a problem with this proposal. Science does not work by this positivist criterion. If we take physics as an example, we find this criterion inapplicable. The lack of an explicit definition (operational or observational) of a term is not limiting in the development of physical theories. Hence, the requirement to express unobservables in observational terms is not essential in science.

Likewise, explicit definitions entail logical difficulties for many scientific terms such as dispositional terms that indicate the disposition of an object to show, in certain circumstances, certain behavior. This logical difficulty can be illustrated through the following example:

Take the predicate 'water soluble' (S). Introduce the predicate S based on two predicates A and D, such that Axt means 'the body x is placed in water at time t' and Dxt 'the body x dissolves at time t'. We say that if 'x is soluble in water' then 'if x is put in water, x dissolves." That is,

$$S_x \leftrightarrow \forall t(Axt \rightarrow Dxt)$$

By virtue of material implication, the *definiens* (the defining expression) would be true even if Axt were false, which would make the truth or falsity of Dxt indifferent by eliminating the usefulness of the definition. In other words, if x is not put in water, we can affirm that it meets the definition of 'soluble'.

Under this analysis, Rudolph Carnap admits that it is impossible to define theoretical terms by means of strictly observational expressions. In an attempt to solve the difficulty, he proposes to use implicit definition in which the theoretical *definiendum* is no longer isolated from the *definiens* that contains the observational terms.

Specifically, Carnap's proposal is summarized in relating theoretical and observational terms using reduction statements. While understanding reduction statements of the type $Cx \supset (Qx \equiv Ex)$, i.e., 'If the test condition C applies to x, then x has the property Q if and only if x manifests the property E', only a partial interpretation of 'Q' is given, in the sense that this formulation specifies the meaning of 'Q' only for objects that satisfy test conditions C. In this way, the meaning of Q is left 'open' in the sense that it is always possible to add more reduction statements, offering more conditions and answers (with the property E) to prove the presence of Q. (Olivé & Ransanz, 1989, 59)

Through reduction statements theoretical terms receive a partial interpretation conditioned to specific circumstances, that is, to a particular set of experiments and a particular set of results obtained from the experiments. We can apply Carnap's proposal to the example indicated above.

Let us consider a new predicate R that we introduce into our language by means of a reduction pair, where P and S denote the control conditions and Q and T the results of the experiment performed. We express these conditions as follows:

$$\forall x \forall t[P_{xt} \rightarrow (Qxt \rightarrow Rxt)]$$

$$\forall x \forall t[S_{xt} \rightarrow (Txt \rightarrow \neg Rxt)]$$

The first reduction statement for 'soluble' could be: 'if an object is put in water, then if it dissolves then it is said to be soluble'. If P and S are identical, and Q and T are contradictory, we will have:

$$\forall x \forall t[P_{xt} \rightarrow (Qxt \rightarrow Rxt)]$$

$$\forall x \forall t[P_{xt} \rightarrow (\neg Qxt \rightarrow \neg Rxt)]$$

It is reducible to:

$$\forall x \forall t[P_{xt} \rightarrow (Qxt \leftrightarrow Rxt)]$$

In general, the introduction of a new term occurs through the constitution of at least one pair of universal propositions (bilateral reduction statements) whose function is to establish a concrete case in which the predicate in question is applicable and another in which it is not. By applying this method, the obstacle of the characteristic of material implication disappears, since the reduction statements limit the introduction of the term to the specified control conditions, avoiding the defects that the explicit definition presupposes.

This Carnapian proposal implied a significant weakening of the original empiricist program. Theoretical terms no longer required to be defined by reference to observable things, but received a partial interpretation of a particular set of experiments and a particular set of results of these experiments. Though Carnap's proposal seemed to be a partial solution to the problem, it was not entirely satisfactory to many positivists. His intention was to avoid abandoning the general aim of empiricism. Thus, even having given up the notion of eliminating theoretical terms in favor of observable entities, he still maintained that terms introduced by reduction statements had, in a sense, been reduced to observable entities.

Carnap distinguishes the laws of science as empirical and theoretical. He catalogs theoretical terms as unobservable entities, and non-theoretical terms as observable. Note that he 1) clubs unobservables and theoretical entities into one, and 2) does not recognize the inevitable mutual continuity between theoretical and empirical terms. Carnap argues:

> Empirical laws are those that can be directly confirmed by empirical observations. The term 'observable' is often used to designate a phenomenon that can be directly observed. (…) Philosophers and scientists use the terms 'observable' and 'unobservable' very differently. For a philosopher, 'observable' has a narrower meaning. It applies to properties such as 'blue', 'hard', 'hot', etc. They are properties that are perceived directly through the senses. For the physicist, the word has a much broader meaning. It includes any quantitative magnitude that can be measured in a relatively simple and direct way (....) The physicist would not say that the mass of a molecule, and even less that of an electron, is something observable, because in this case the procedure of measurement is much more complicated and indirect. But the quantities that can be determined by relatively simple procedures – length with a ruler, time with a watch, or frequency of light waves with a spectrometer – are called observables. (Carnap, 1969, 299)

Empirical laws refer to observables in this way. From this point, and following Carnap's line of argument, the distinction is made between 'unobservable' (theoretical term) and 'observable' (non-theoretical term), contrasting the philosophical and physical vision. Again, note that he does not differentiate between unobservables and partial unobservables.

According to Carnap, philosophers understand by unobservable a simple and direct measurement of some physical magnitude, while they refer to perceived sensory properties as observable. However, for physicists the distinction is somewhat more complex. For Carnap, they understand as observable those terms that are directly observable by the senses

or measurable by relatively simple techniques (e.g., pressure, volume, temperature, humidity, weight, etc.), while by unobservable they understand those terms whose measurement procedures are complicated and indirect – electron, force, energy, field, gravity, space, time…. Note that the last two (space, time) are merely the epistemic conditions (hence, epistemic universals, i.e., essences) for the possibility of actual measurements and quantities – a fact that physicists and philosophers of more than two millennia have forgotten – the implications of which will appear clearer later in the present work.

Regarding theoretical laws, Carnap expounds:

> There is no commonly accepted name for the (…) laws, which I call theoretical laws. They are sometimes called abstract or hypothetical laws. (…) A theoretical law is not distinguished from an empirical law by the fact that it is not well established, but by the fact that it contains terms of a different kind. The terms of a theoretical law do not refer to observables even when the broad meaning that the physicist gives to what can be observed is adopted. They are laws about entities such as molecules, atoms, electrons, protons, electromagnetic fields, etc., which cannot be measured simply and directly. (Carnap, 1969, 299)

Thus, for Carnap, theoretical laws are made up of theoretical entities. Determination of the meaning of an unobservable entity or theoretical term is carried out through the axioms of scientific theory. (Carnap, 1969, 300) From here, one obtains a vantage to theoretical terms under the theoretical perspective.[2] He says, "(…) a complete semantics of theoretical terms in science implies a statement about scientific realism and its alternatives. This semantics can also imply an explanation of how observation is related to theory in science." (Carnap, 1969, 300)

Beyond the acceptance of scientific realism, what is involved here is the recognition that within the language of science both theoretical and unobservable entities, separately, are necessary, their participation in the advancement and predictive nature of science being undeniable. Take for example the case of neutrinos. Almost all physicists of the time assumed that the attributions (properties) given to neutrinos made their detection impossible.[3] However, not accepting the existence of neutrinos meant abandoning the principle of Conservation of Energy, thereby disproving much of physics. Theory prevailed over observation here. Thus, neutrino joined the group of unobservables. In 1956, Clyde Cowan and Frederick Reines proved their existence experimentally.

The highlight of this example is that neutrino was introduced *ad hoc* by Wolfgang Pauli, assuming that it was impossible to observe it. Later, theory changed observation. This shows the difficulty of drawing a line between observables and unobservables. Modern physics makes it irrelevant that each term is defined and accepted only in reference to a set of sensory data. In fact, physics contains many terms that refer to both unobservable and theoretical entities not expressed in sensory terms. Hence, both unobservable and theoretical terms and their "counterpart entities" are foundational for scientific theory.

1.3. Unobservables and Theoretical Entities in Recent Theories of Significance

Another attempt to give a solution to the problem is the so-called contextual theory of meaning. It shows dependence on incorporation of the meaning of a scientific term within a scientific theory. It goes back to the postulations of Pierre Duhem who, in contrast to the positivism of his time, held from an epistemological viewpoint that theories take priority over experience. But at the end of the present article, I shall qualify this statement by claiming that two metaphysical Categories as criteria of determination of the difference between purely theoretical terms (and their objects as conceptual qualities and their confluences) and theoretically constructed existent-conveyors (with their objects as existent processes) take priority in theory and experience.

According to Duhem, experience is not the starting point for scientists to formulate theories. On the contrary, scientists depend on a theoretical background and from there they carry out experiences to make postulations and/or theories more precise. For him, the theory-experience dichotomy is the result of the interpretation of the data obtained in an experiment. There are no pure experiences or observations. Every observation is accompanied by a different interpretation from the

[2] Carnap argues explicitly: "Various semantics have been devised that aim to explain how a scientific theory contributes to the interpretation of its theoretical terms and, as such, determines what they mean and how they are understood. All these semantics assume that the respective theory is given axiomatically. However, theoretical terms are also recognizable in scientific theories that have hitherto resisted satisfactory axiomatization. This is due to the fact that these theories contain general propositions that have the logical form of universal axioms." (Carnap, 1969, 299-301)

[3] The existence of the neutrino was proposed in 1930 by Wolfgang Pauli to compensate for the apparent loss of energy and linear momentum in the β decay of neutrons according to the formula $n \rightarrow p^{+} + e^{-} + \bar{v}_{e}$. Pauli concluded that both mass and energy would be conserved if a hypothetical particle (neutrino) participated in the decay by incorporating the lost quantities. Neutrino had to be without mass, charge and strong interaction, which made its detection impossible at the time. Its hypothetical nature made it an unobservable for 25 years. For an exhaustive review of the properties and kinds of neutrinos, consult the Nakamura data. (Nakamura, 2010, 37)

ordinary one. In short, in a physical experience the verification of facts cannot be dissociated or separated from the transformation that they undergo by the application of the theory.

He maintains: "(…) the phenomena actually observed by the physicist are interpreted according to the assumed theory." (Duhem, 1978, 171) His assertion that it is physical theories that give meaning to specific concepts in physics leads to the view that a hypothesis in physics accounts for semantic considerations. Perhaps the most prominent and explicit formulation of the contextual theory of meaning is found in the ideas expounded by Paul Feyerabend:

> Because just as the meaning of a term is not an intrinsic property but depends on the way the term has been incorporated into a theory, in the same way the content of a complete theory (and therefore, again, the meaning of the description of terms it contains) depends on the way in which it is incorporated both in the set of its empirical consequences and in the set of all the alternatives that are discussed at a given moment: once the contextual theory of meaning has been adopted, there is no reason to limit its application to a single theory, especially since the limits of such a language or such a theory are almost never well defined. (Feyerabend, 1962, 88)

From this viewpoint, the contextual theory of meaning accounts for the meaning of a concept without direct basis in experience. Such meaning occupies a role within a logical system. The meaning of a term must be understood as that which determines its reference. Thus, a semantic theory must account for our understanding of meaning and, therefore, also our methods of determining the extent of meaning of scientific terms.[4]

Following Duhem, the problem of unobservable entities consists in giving an adequate explanation of the meaning and reference, by distinguishing between (1) unary predicates that refer to theoretical and unobservable entities and (2) theoretical functions (e.g., 'force', 'temperature', 'electromagnetic field strength'). Around Duhem's thesis orbit the postulations of some philosophers within scientific realism, e.g., Hanson, Kuhn, Lakatos, Putnam, Feyerabend…. The meeting point between realists is the need to show that observational terms are loaded with theory. Meaning depends on the context given by theory.

Hilary Putnam maintains that the logical-empiricist explanation of the meanings of theoretical terms is based on the combination of two distinctions. Feyerabend (1962, 32) assumes that all terms are theoretical. Hanson and Kuhn argue for non-existence of a neutral observational language considering that, if all language has theoretical presuppositions, then there seems to be no basis for supposing that the language that claims to speak of unobservables should be treated differently from the language of observables.

Deriving from these universally acceptable postulations and taking the affirmations by Carnap, Hermann Weyl identified in 1949 different exemplifications maintaining that the axioms of a scientific theory determine the meaning of theoretical terms, without the axioms qualifying as adequate definitions of theoretical terms. This idea has become almost constitutive of the very notion of an unobservable entity in the philosophy of science. Weyl argues:

> One more remark illustrating the situation by a typical example (…): In formalized mathematics a symbol → occurs between formulas; e.g., a → b. This formula a → b has replaced the statement that the proposition a implies b or that b follows from a. It recalls and points to this logical concept of implication, although now it has become a meaningless symbol. On the other hand, when we play the game of deduction and start with a certain formula a we may arrive at b we could then say: As our deduction shows, b follows from a. This "follows" has a meaning, and looking down, as it were, with our mind's eye on the game we convey by our words a meaningful statement about what has happened in the game. In practice we are careless enough to enunciate our mathematical theorems in words rather than in formulas, as if they still kept their old meaning. But in principle we must sharply distinguish between the symbol →occurring within the system, and such words as "follows" which we use to make meaningful communications about the game. (Weyl, 2009, 187)

Following the same order of ideas, Weyl illustrates:

> We move in the world of our seeing, acting, caring, natural life, and by no means in the realm of the immediate sensual data of consciousness, about which the positivists used to talk so much; in a world so infinitely more obvious and familiar to every one of us, although the suspicious analyzing intellect finds it bewilderingly complex and muddy. As scientists we may be tempted to argue: As we know, the chalk on the blackboard consists of molecules, and these are swarms of charged and uncharged electrons, neutrons, etc., which ultimately dissolve again into mere symbols and formulas, which in their turn are written with chalk on a blackboard". (Weyl, 2009, 187)

Taking two common and familiar objects (chalk and blackboard) as an example, Weyl accounts for unobservable entities (atoms, neutrons, electrons) through intuitive language. For Weyl, the symbolic construction should be left without explaining what mass, charge, field intensity, etc. mean; and then try to describe how this structure is related to immediate

[4] Duhem maintains: "*An experience in physics consists of the precise observation of a group of phenomena accompanied by their* interpretation; *the latter replaces the data collected through the observation of abstract representations and corresponding symbols, by virtue of the theory assumed by the observer*." (Duhem, 1978, 164) Emphasis in the original Italian.

experience, which leads us to consider not only the way in which we express terms and their meanings through a logical-semantic system, but also consider the role of consciousness when we are facing a phenomenon.

In other words, for Weyl scientific theories have two aspects: a symbolic side and another that accounts for consciousness. Symbolic descriptions present in theories do not 'show' unobservable entities. Instead, they account for variables. Thus, in the case of space-time, there are four independent variables that 'show' recognizable quantities. On the side of consciousness, one must talk about intuitive perceptions of space, time, etc., e.g., coincidences in space.

The connection between the symbolic and consciousness sides shows the complex unity of scientific theories. Weyl argues in this regard that "(…) the situation becomes considerably more complex if we abandon our unpardonable idealizations. An individual law isolated from theoretical structure simply floats in the air. Ultimately, all parts of physics, including geometry, merge into an indissoluble unity." (Weyl, 2009, 184) This conviction in interconnectedness comes to my rescue at the end of the article, where I opt for an all-inclusive couple of Categories for all science and philosophy.

Following Weyl, 'reality' must be put in quotation marks. When we have a symbolic construction, we have no guarantee that it truly refers to the real world. How to guarantee that we 'observe' and not 'interpret', and that non-theoretical or observational terms come from pure observation? For example, when we 'see' some object in space, do we 'unconsciously' assume knowledge of the geometry of space? And in relation to unobservables: Do scientists not 'observe' atoms, protons, quarks, and neutrinos? Certainly, only their effects are observed. But, although they cannot be observed directly, and we only account for their effects, is this enough to classify them as unobservables and theoretical entities? Some philosophical positions, unable to shed and protest against the absolutely materialist-realist idea of observation, hold that no material object can be observed, but only the effects they produce on our senses or minds.

In this regard, and without assuming radical positions like existence of matter alone without having to insert universals in processes, I suggest: as is derivable from Weyl's considerations, it is necessary to study the role that the epistemic (knowledge-level, scientific, instrumentation-level, etc.) status of consciousness plays in the afore-mentioned theory-observation dualism. The point is to direct efforts towards a meeting point between the various positions that analyze the status of unobservable and theoretical entities within scientific theories and to facilitate the status of theories in a broadly tenable way by including whatever 'entities' that pertain to processes and their conscious reflections.

Grover Maxwell assumes an intermediate position between the postulations that study the problem, pointing out that the concept of the observable varies with the range of available devices. Many are unable to observe much without putting pieces of glass (or plastic) between their eyes and the world. More is seen using magnifying glasses, microscopes, telescopes, and other devices. There is an apparent continuum here. Maxwell asks where the decisive ontological shift should be marked, and at what point the entities believed to be observed should not be counted as real. Maxwell begins his article as follows:

> The fact that anyone today can seriously argue that the entities to which scientific theories refer are only convenient fictions, or that what is said about such entities is fully translatable in terms of pure sensory contents or everyday physical objects, or that talking about such entities should be considered as part of a mere calculation device and, therefore, without cognitive content, all this seems to me so incongruous with the scientific and rational attitude and practice (….) (Maxwell, 1989, 116)

He supports a line that argues from a brief reconstruction of the different positions that analyze the theory-observation dichotomy. At each stage he 'dismantles' the different philosophical theses that he reviews. Following Maxwell's critical reconstruction, it can be argued that the problem of unobservable entities has been reduced by the philosophical currents of realism and instrumentalism to the linguistic or terminological domain, while phenomenal currents reduce it to the sensory. Maxwell does not favor them. He assumes an intermediate position that he calls "radical scientific realism". (Uribe, 2014, 171, 193)

The dividing line between 'unobservables' and 'observables' is blurred. It does not diminish the importance of the basis of observation. It is true that some considerations about phenomenalism can shed some light on the theoretical-observational dichotomy. This does not imply leaving aside the other side of the dualism (experience). In this regard, Maxwell admits: "I am not among the philosophers who maintain that there are no sensory contents (…) nor do I believe that they do not play an important role in our perception of reality. But the fact remains that the referents of most of the statements (…) are not sensory contents but physical objects." (Maxwell, 1989, 128)

For Maxwell, his postulation's success lies in a scientific-theoretical question and not a logical, epistemological, or conceptual one. He maintains that the key point about making a decision about the truth or falsity of an observation statement focuses on scientific advances and the consequent use of the observation language of physical objects and the treatment of sensory contents as theoretical entities. But note that Maxwell's assumption does not hold sensory contents as 'unique' theoretical entities, but as a type of these. For Maxwell it is always possible to observe other types of entities that were once theoretical, different from the contents of sense data.

How is the observation of theoretical entities possible? From Maxwell's perspective, observation is supported through advances in scientific instrumentation. Through the knowledge acquired of the world, it is possible to 'see directly' many

of the types of theoretical entities (electron, Higgs boson, etc.). Maxwell concludes: "(…) drawing the theoretical-observational line (…) is an accident and a function of our physiological constitution of the current state of our knowledge and of the instruments that are accessible to us at that moment and, therefore, that has no ontological significance." (Maxwell, 1989, 130)

A position different from Maxwell's 'radical scientific realism' is that of Wesley Salmon. He takes into consideration the historical process through which scientists became convinced of the reality of atoms. Focusing on the work of the physicist Jean Perrin (1870-1942), Salmon points out that there are many, apparently independent, methods that determine the values of quantities referred to unobservable entities, each of which provides the same answer with compelling inductive evidence. (Salmon, 1997, 77)

In opposition to the postulations of realism, Van Fraassen postulates 'constructive empiricism'. He tries to capture the ideas of logical empiricism, purportedly avoiding its defects, under the proposal of constructing in science models designed to 'save the phenomena' that make it possible to obtain correct predictions about observables. From his viewpoint, adopting models is simply assuming that observable events and states of affairs account for the models as if models were true, but without committing to the existence of unobservable entities and processes listed in the models. Van Fraassen assumes a neutral position regarding unobservables. His basis is that, in science, in order to achieve correct predictions about observables, it is not necessary to assume the risks that a commitment to the existence of unobservables implies. (Van Fraassen, 1980, 19)

Following the antirealist line, we find the formulation offered by Arthur Fine. He points out that realists try to convince their opponents under the premise that only a purely realist view of unobservables explains the success of science, assuming that it is a sufficient condition for accepting a theory with its explanatory power. The key point of antirealist arguments is that explanatory power has nothing to do with the veracity of theory. One strong reply by realists is that anti-realists cannot explain important aspects of scientific practice. Realists hold that, for example, putting together theoretical claims from different scientific theories (e.g., when scientists on earth rely on parts of physics and chemistry) would be meaningless if there were no such thing as a serious commitment to the approximate truth of theoretical principles. (Fine, 1986, 115)

Realists, thus, hold that the kinds of inferences that antirealists recognize as unproblematic (e.g., generalization of observed samples to conclude about a larger population of observables) can only be made in light of an understanding of the fact of unobservable entities. One cannot tell what makes a sample suitable for generalization unless one has opinions about the ways the sample might be biased. That usually involves beliefs at least about relevant unobservable causes. Anti-realists must demonstrate that they have the resources to make sense of these and other features of scientific practice or offer reasons to think that the procedures in question should be revised.

The complex problems of truth in science naturally reach the technical areas of theoretically all-embracing metaphysics and not so all-embracing philosophy of language. Some hold it impossible to follow any theory of truth. They forget that asserting the truth of their statement is another way of asserting the never-absolutely realized concept of truth itself. Fine, in the context of his midway-realism in philosophy of science, proposes rightly that neither realism nor antirealism is tenable. But it would be a self-goal and re-igniting of crass instrumentalism, as he stops discussing the ideal of truth in relation to scientific hypotheses and adopts merely what he calls the 'natural ontological attitude' (Fine, 1986, 122ff) – that is, endorse the claims made by contemporary science without falling into the unnecessary philosophical flourishing of stating they are 'true' – without ontological universals and essences. The problems is, science too claims having tested truths!

These sophisticated proposals contrast with a more accessible critique of the idea of 'scientific truth' that also stems from the suspicion by Kuhn and Weyl. For Weyl it would make no sense to exclude the role of ontological universals in things, and of their essences in the mind, from truth as the ideal of correspondence. In this way, the debate around intelligible theoretical terms, unobservable entities, and observable entities can remain in full force.

Although the sophistication of scientific instrumentation has made it possible to detect entities previously considered unobservable (neutrinos, gravitational waves, Higgs boson, etc.), observation concepts that apply to unobservables persist, which we understand only in terms of universals. General examples including partial unobservables are theoretical terms denoting energy, gravitational field, electromagnetic field, spatio-temporal relationships, inertia, force, etc.

Debate about the reality of unobservables that scientific theories postulate never ends. Fresh unobservables appear frequently. Hence, when addressing the problem of unobservables, scientists and philosophers must go beyond addressing only the theory-observation dichotomy. They should address another set of problems: What is a real thing "in general"? Are there characteristics (ontological universals) of existents that should match their concepts (which use essences)? What is truth if observations do not match reality as such? What guarantees descriptions to be accurate enough?

I believe instituting the two fundamental Categorial criteria of existence as necessarily reflected in their concepts would do the trick of answering these questions more adequately than when without them. Some unobservable entities represented by theoretical constructs are most probably existent, but as yet not proved with sufficient certainty. These are not the same as theoretical entities. Inexistent unobservables (proved so in time) are mere conglomerates of essences in theory. But, as

we shall see, essences play a role in scientific theory – especially of unobservables and theoretical entities – as Husserl proves. In effect, as seen above, the whole of positivist, instrumentalist, pragmatist, and most of analytic, traditions in philosophy of science have thought differently. I seek a permanent solution to this problem in physics and philosophy of science, by going the way of Husserl and then going beyond it. I use universals and essences to further the cause of two Categorial criteria of existence for unobservables and theoretical terms.

2. Unobservables, Theoretical Entities, Husserlian Essences, and Extension-Change

The possibility of use of unobservables in science is not alien to phenomenology. For Husserl, postulation of unobservables is typical of scientific work and creates a scientific method using them. It contributes to the achievement of the evidence required of true science. Exposing Husserl's ideas requires the use and understanding of his terminology. It entails considerable complexity. Carrying out an extensive exposition of the development of phenomenology exceeds my objective. I indicate only some phenomenological aspects relevant for the theme.

Experiencing something creates the problem of how we know. In general terms, knowledge of an object is well realized if a judgment on that object corresponds to the object in question provided it is presented immediately or directly. (Aguirre-García, 2014, 294) However, as seen in the previous section, ideal truth as "correspondence", a rationalist-empiricist position inherited from the Ancients and Medievals, is inadequate to address unobservable entities and theoretical terms, although the ideal must remain in discussion.

Knowing is different from ideal truth. Knowing is the question that runs across the development of phenomenology. Husserl says: "Knowledge, in all its forms (…) is knowledge of the subject who knows. In front of him are known objects. But how can knowledge be certain of its adequacy to known objects? (…) The occurrence of the objects of knowledge in knowledge (…) becomes an enigma." (Husserl, 1982, 29)

From the study of the meaning of knowledge, questions arise regarding the guarantee in the relationship between the reality and the 'self-givenness (*Selbstgegebenheit*) of the object' to knowledge. The real significance of self-givenness (*Selbstgegebenheit*) is discussed by George Heffernan:

> According to Husserl's mature phenomenological definition, evidence is "the *intentional achievement of self-givenness*" ("*die intentionale Leistung der Selbstgebung*" [XVII 166]). This "givenness" is as much an achievement of the *having* subjectivity as it is a function of the *given* objectivity. Hence Husserl's concept of the "given" is, properly understood, also a concept of the "taken". (Heffernan, 2009, 24)

Under the premise 'return to things themselves', Husserl studies the problem of knowledge under the postulation of the 'Principle of all Principles' (PP) in his *Ideas Pertaining to a Pure Phenomenology and a Phenomenological Philosophy (Ideas I).* Thus, in section §24 entitled "Erroneous naturalistic interpretations" Husserl postulates: "(…) the *principle of all principles: that every originary presentive intuition is a legitimizing source of cognition,* that *everything originarily* (so to speak, in its "personal" actuality) *offered* to us *in* "*intuition*" *is to be accepted simply as what it is presented as being,* but also *only within the limits in which it is presented there*." (Husserl, 1982, 44)

'Giving intuition' is for Husserl the first sphere of knowledge: "(…) the first sphere of knowledge, the 'natural', and of all its sciences, is the natural experience, and the ORIGINALLY giving experience is PERCEPTION, understood as the word in the ordinary sense."[5] (Husserl, 2013, 87) in this way, according to PP, the key consists in understanding the 'original self' and clarifying the notion of 'intuition' within the phenomenological framework in order to enable an approach to the response of how we know. From this viewpoint, it is natural to move away from positions that seek to base all knowledge on experience (empiricism) and the 'substantial self' behind the sensory or perceptual sphere. Husserl notes:

> (…) [T]he error of principle of the argumentation / empiricist lies in identifying or confusing the fundamental exigency of a return to "things themselves" with the exigency of founding all knowledge on experience. Given the understandable naturalistic limitation of the framework of knowable "THINGS", for the empiricist experience simply transpires as the only act that gives things themselves. But THINGS are NOT simply NATURAL THINGS, reality in the ordinary sense is not simply reality in general, and ONLY TO THE NATURAL REALITY refers the act which originally gives us what we call EXPERIENCE. (Husserl, 2013, 120)

Emphasizing these remarks, he maintains: "(…) whether something merely represented, or something truly existent, something real or something ideal, something possible or something impossible, is manifested in it, giving is a giving in the *phenomenon of knowledge*, in the phenomenon of a thought in the broadest sense of the word." (Husserl, 1982, 88) That is, for him an intuition limited to sensory experience is impossible. The 'original giving' is not reduced by

[5] Emphasis by capitals in the original Spanish.

seeing empirically. I opine: This and similar claims by Husserl demonstrate also his commitment to the vaguely or almost impossibly perceivable unobservables – physically however minute –, and theoretical entities that appertain even to sensation and imagination, let alone understanding and theorizing.

Husserl argues that a perception of objects that seeks to establish adequacy in the narrow margins of sense perception is doomed to failure, due to inadequacy in perception. Therefore, both the natural scientist and the phenomenologist have the duty to rigorously determine the thing perceived, but not exclusively in the domain of sensible perception,[6] (Aguirre-García, 2014, 296) although unobservables are a vaguely determinate type, and parallelly, theoretical entities are a vague and indeterminate type of entities.

Clearly, Husserl's PP must be understood in a sense beyond the empiricist framework. The intuition of 'original giving' should not be confused with the immediate presence of something. They are not the same. Something connects them. Although Husserl's critical postulations sufficiently account for a weak empiricist legitimation between knowledge and sensible perception, the key axis in phenomenology is the development of the concept of intuition of essences. What connects the original giving with the immediate presence is the intentionality and intersubjectivity, and what makes the connecting objectively possible are the objects termed essences, gained respectively under various aspects of the giving and taking.

The objective aspect in intentionality is the essences, because they are the fundamental generalities in the intentionality in terms of whatever give themselves to the subject, and remain available highly objectively in language and mind in intersubjective commitment to truth. The merely subjective in intentionality with respect to truth are due to deficits in methodological application of bracketing and eidetic reduction in the analysis of perception, thought, etc., wherein, due to the deficits, essences are disclosed vaguely.

Husserl's notion of intuition has its genesis in Kantian ideas, evidencing a duality: empirical intuition understood as consciousness of individual objects (for Husserl, *noesis*, 'objective act quality') and eidetic (for Husserl, *noema*, 'act matter' that is objectivated in the act, but in *eidos*) intuition of intentional objects which is consciousness of structured forms (essences). Starting from the empirical object, eidetic intuition takes the object in general, that is, as universal, *a priori*. Thus, under the phenomenological description the various modes of being of the thing in intentionality (essences) are analyzed.

The phenomenon perceived under the intentional attitude is the 'relative object', i.e., the object-qualified *noema* of all objects or phenomena showing-themselves. It is relative because it may be taken as what is given under the natural empirical attitude, which is not close enough to what the phenomenon is – thus yielding inadequately researched knowledge, e.g., knowledge acquired by sciences without intentional research by the obsolescent (antiquated) scientistic-natural attitude. Sieving phenomena through the object-qualified *noemata* that pertain to the intentional attitude, by and beyond the act of *noesis*, is thus the phenomenological method.

By the above duality in the concept of intuition we understand the concept under the primary and secondary connotations. Empirical intuition is the primary, and eidetic intuition the secondary. The primary sense does not give a special status to intuitive knowledge beyond the attention paid to what is immediately given in experience. Emphasizing the distinction between 'immediate seeing' and 'seeing in general', we say: primary intuition provides the fulfillments of our *noemata*, showing in this way that it is not the subject who freely chooses the fulfillments, but they are 'given' in experience. Husserl argues:

> *Immediate* "*Seeing*", not merely sensuous, experiential seeing, *but seeing in the universal sense as an originally presentive consciousness of any kind whatever*, is the ultimate legitimizing source of all rational affirmations. This source has its legitimizing function only because, and to the extent that, it is an originally presentive source. If we see an object with full clarity, if we have effected an explication and a conceptual apprehension purely on the basis of the seeing and within the

[6] Husserl: "ONLY ANOTHER WAY OF EXPRESSING just the same would be – SO THE EMPIRIST BELIEVES – the affirmation that all science start from EXPERIENCE, would have to FOUND its mediate knowledge in an immediate experience. Thus, authentic science and science of experience are wholly the same for the empiricist. "Ideas", "essences" as against facts – what else would they be than scholastic entities, than metaphysical ghosts? To have redeemed humanity from such a philosophical mirage is precisely the great merit of modern natural science. Only with the experienceable, real reality, would all science have to do. What is not reality, is imagination, and a science based on imaginations is precisely imaginary science. One would permit imaginations as psychic facts, they belong to psychology. That from (…) imaginations must emerge, through a so-called essential vision founded on them, new data [*Gegebenheiten*], "eidetic" [data], objects, that are *unreal*, that is – the empiricist will conclude – precisely "ideological eccentricity", a "regression to scholasticism" or to that kind of "*a priori* speculative constructions" through which idealism alien to natural science so much hindered genuine science in the first half of the 19th century.

However, what the empiricist says there rests on misunderstandings and prejudices – no matter how well-intentioned and good the motive that originally guided him may be." (Husserl, 2013, 119-120). Emphasis in capitals in the Spanish. Translation mine, in comparison with the German.

> limits of what is actually seized upon in seeing, if we then see (this being a new mode of "seeing") how the object is, the faithful expressive statement has, as a consequence, its legitimacy. (Husserl, 1982, 37)

Hence, 'immediate seeing' in the universal, originally presentive sense is the form of consciousness in which something is originally given. Having access to this form of consciousness undergoes the phenomenological reductions that the distinction between the natural attitude (science) and the intellectual philosophical attitude (reflection) require for its execution. Accessing a 'critical vision' of knowledge requires a transition from the natural to the reflective attitude. Husserl postulates a way of solving the problems inherent in the meaning and object of knowledge by introducing the essences in knowledge:

> At first "essence" designated what is to be found in the very own being of an individuum as the What of an individuum. Any such What can, however, be "*put into an idea*." Experiencing, or *intuition of something individual* can become transmuted into *eidetic seeing (ideation)*, a possibility which is itself to be understood not as empirical, but as eidetic. What is seen when that occurs is the corresponding *pure* essence, or Eidos, whether it be the highest category or a particularization thereof – down to full concretion.
>
> This seeing which is *presentive* of the essence and, *perhaps, presentive of it originarily*, can be an *adequate* one such as we can easily obtain in, for example, a seeing of the essence tone. (…)
>
> The essence (Eidos) is a new sort of object. Just as the datum of individual or experiencing intuition is an individual object, so the datum of eidetic intuition is a pure essence. (Husserl, 1982, 8-9)

Essence is a new type of an individual object delivered in an eidetic vision. Experience is primarily an empirical vision, the consciousness of an individual object. What is seen when that happens is the corresponding pure essence, or *eidos*, either of a superior category or a particularization of it until its total concretion. The specific character of certain categories of essences is such that the essences that belong to them can only occur unilaterally, in a sequence of many faces / aspects, but never absolutely generalized. That is, each essence related to something physical is a composition of different layers of multifaceted vision.

Mastrobisi maintains: "This *eidos* must manifest itself through all the potential forms of mental being in particular cases, must be present in all the synthetic combinations and self-enclosed wholes, if it is to be at all *thinkable* that is, intuitively conceivable." (Mastrobisi, 2018, 352) Under this point of view, Husserl formulates the method that can clarify the essence and object of knowledge through an attitude change and give access to regions of being through gradual and voluntary reductions by the subject who knows. Thus, through the phenomenological attitude, reality (*cogitatum* / *noema*) is inserted into consciousness, being an experience (*cogitatio* / *noesis*) in consciousness that preserves the guarantee of the objective properties and extension of the reality, to which belongs the subject who knows. (Aguirre-García, 2014, 298)

In this way, what is given to intuition in the primary sense (sensitive perception) is achieved from phenomenological reductions, allowing the subject who knows to explore the meaning of the object. Bernet calls it 'constitutive phenomenology'. (Bernet, 2004, 2) Under the assumption of the reflective attitude, it accounts for the *intentionality* which goes on to show the relationship between the world and consciousness through the unbreakable subject-object connection. "Husserl (1917) clearly says that the experience of something external, of something physical is itself a mental experience, but related to the physical through our intentional experience." (Mastrobisi, 2018, 352)

Husserl claims a "specifically philosophical", reflective, 'intentional' attitude that grounds the belonging of unobservables to the *physical intellectio*. In *Logical Investigations I*, Husserl understands knowing as the how of possessing truth, specifying 'truth' as 'subject to a fair trial'. (Husserl, 1982 c, 17) He clarifies:

> (…) not every correct judgment, every affirmation or rejection of a state of affairs that with truth, represents *knowledge* of the being or non-being of this state of affairs. Rather we may say that, if it is to be called 'knowledge' in the narrowest, strictest sense, it requires to be evident, to have the luminous certainty that what we have acknowledged *is*, that what we have rejected *is not*, a certainty distinguished in familiar fashion from blind belief (….) (Husserl, 1982 c, 17)

Under the terms in which Husserl indicates 'evidence' as 'the luminous certainty', the absolute character that he grants to the evidence is allowed to be glimpsed. Despite such claims, Husserl is aware that science does not reach an 'absolute evidence'. Hence, he opts for 'evidence of probability':

> The most perfect 'mark' of correctness is inward evidence, it counts as an immediate intimation of truth itself. In the vast majority of cases we lack such absolute knowledge of truth, in whose place we make use (…) of the inner evidence for a higher or lower degree of probability for our state of affairs, with which, if probability-levels become high enough, a firm judgment is usually associated. The inward evidence of the probability of a state of affairs *A* will not serve to ground the inward evidence of its truth, but it will serve to ground those comparative, inwardly evident value-assessments, through which, in accordance with positive or negative probability-values, we can distinguish the reasonable from the unreasonable, the better-founded from the worse-founded assumptions, opinions and surmises. (Husserl, 1982 c, 17-18)

He affirms:

> There is none the less a remaining duality in the concept of knowing or knowledge. Knowledge in the narrowest sense of the word is the being inwardly evident that a certain state of affairs is or is not, e.g. that that *S* is *P* or that it is not *P*. If it is evident that a certain state of affairs is probable to this or that degree, then we have knowledge in the strictest sense of such a probability, but, in regard to the being of the state of affairs itself, and not of its probability, we only have knowledge in a wider, modified sense. It is in this latter sense, with an eye to degrees of probability, that one speaks of a greater or lesser degree of knowledge. Knowledge in the pregnant sense – its being quite evident that *S* is *P* then counts as the absolutely fixed, ideal limit which the graded probabilities for the being-*P* of *S* approach asymptotically. (Husserl, 1982 c, 18)

In the two statements above, clearly, Husserl adapts the concept of probability to that of truth and verification through the comparison of some mental representation with some state of affairs outside the mind. (Husserl, 1999, 12) This upholds 'adequacy' and not 'equalization' with the intention of making it clear that for Husserl 'truth' is not 'probability'. In fact, for Husserl, truth turns out to be a supra-empirical ideality. From this viewpoint, and taking into account the case of unobservables in physics, Husserl argues:

> When physics determines the physical thing given exclusively by such concepts as atoms, ions, energies, and so forth, and as, in any case, space-filling processes for which the only characterizations are mathematical expressions, it means them as *something transcendent to the whole physical-thing content standing there* "*in person*." As a consequence, it cannot mean the physical thing as something located in the natural space pertaining to the senses. In other words, the space of physics cannot be the space belonging to the world given "in person" in perception: if it were, then the Berkeleyian objection would also apply to it. (Husserl, 1982 a, 84-85)

Thus, Husserl's conception of science (physics) accounts for the unobservables by not limiting the concept of intuition to sensible perception.

3. Reality-Possibility-Essence, Extension-Change, Unobservables, and Theoretical Entities

Einstein states: "(…) fundamental concepts and laws are free inventions (of the human intellect) that cannot be ascertained *a priori* (either by the nature of the human intellect or in any other way). Fundamental concepts and laws no longer reducible make up the inevitable part of the theory that reason cannot understand (….)" (Einstein, 1980, 132) The inevitable, irreducible parts of theory that Einstein refers to are theoretical entities and unobservables. Are they unaccountable in physics? Is philosophy of science right trying to understand theoretical entities and unobservables underling the fundamental laws of physics? Einstein argues:

> [E]very attempt to deduce the fundamental concepts and laws of mechanics from elementary experiences is doomed to failure. But if it is true that the axiomatic basis cannot be obtained from experience, is it possible to aspire to finding the right path? Even more: wouldn't that straight path exist only as an illusion? Can we believe that experience guides us correctly, when there are theories like classical mechanics that agree with it without understanding the facts in all their depth? To this I answer that, in my opinion, the right path does exist, and that we can find it. (Einstein, 1980, 134)

This reveals the importance of the problem and the existing gap in terms of the requirement of a broad and renewed postulation that enables the understanding of the irreducible (unobservable and theoretical) terms of physical theories. The straight path in Einstein's terms must be constituted by a proposal which is at the forefront of the demands of scientific progress and at the same time is flexible. Phenomenology is presented, in part, also as a treatment of unobservables in physics. Consequently, it communicates the visions of physicists and philosophers through the development of a phenomenology of physics by reformulating the conception of essence and including physical-ontological categories. I call it 'phenomenological scientific realism'.

Mastrobisi, following Husserl, Weyl, and Einstein in the introduction to his *Fenomenologia e Relatività*, explains the reality/world-possibility-essence relationship under the *observer-observed* paradigm (Mastrobisi, 2015, 9), reformulating Husserl's concept of essence by including the notion of possibility. Einstein refers to the observer's role and the distinction between external reality and perception of the knower, as he says: "(…) the faith in an external world (*Außenwelt*) independent of the perceiving subject is the basis of every natural science. However, the perceptions of the senses give indirect indications of this external world, (…) the latter cannot be apprehended by us except through speculative (theoretical or philosophical)." (Einstein, 1980, 194)

Scientific endeavour finds it easy to admit that many of its conceptual foundations are not verified by direct observation, and were conceived under theoretical speculation that contains inexistent entities. Thus, theoretical and unobservable entities (including laws) make up the foundational conceptions of scientific theories. So, how to guarantee objectivity in science philosophically?

Neelamkavil's *Gravitational Coalescence Paradox and Cosmogenetic Causality in Quantum Astrophysical Cosmology* postulates the ontological universals: 'Extension-Change', as the physical-ontological categories that meet these demands.

These comply with the processual aspect of entities and allow the invariant structures underlying the world – ontological universals and essences in mutual cooperation. The merit is that he posits 'ontological universals' as the general pertinent structures of the process of Reality and accepts Husserlian essences as Cogito-based 'connotative universals'. (Neelamkavil, 2018, 106, 131-133)

Existents are treated in metaphysics under their possible existence, origin, and evolution insofar as they are non-empty processual existents. Metaphysics is more concerned with existents in their fundamental processual characteristic universals (that make existence possible), while ontology is more concerned with the description of existents and their pertinent 'reals', i.e., ontological universals. In Husserl's methodology, the stress is naturally on the consciously received aspect of ontological universals, i.e., as essences in the Cogito.

My contribution here is a complementation of the vision of reality-possibility-essence (Mastrobisi) by the physical-ontological Categories: Extension-Change (Neelamkavil), whose epistemic essences are space-time (Husserl). This conjugation accounts for 1) the dynamic-multifaceted-processual character of phenomena and reality, 2) the invariant structures of Cogito-level reflections (essences) of ontological universals, categorized under Extension-Change, and 3) the role of intentionality-cum-intersubjectivity in the object-subject-reality relationship evidencing 'possibilities' (foundational ontological universals and essences / connotatives) as key elements in physical theory.

In this sense (and very briefly) I begin expounding each of the reality-possibility-essence triad, then connect the triad through Neelamkavil's Extension-Change categories, and finally use the conjugation between Husserl's and Neelamkavil's perspectives to conceptualize unobservables in physics.

3.1. The Reality-Possibility-Essence Triad

The constitution, the 'what is', 'what something consists of', is its form: in Platonic-Aristotelian terms the *eidos* in entities, and in Husserlian methodology the *eidos* given in Cogito by reason of the giving of processes to Cogito. Mastrobisi assumes Husserl's phenomenological method of 'return to things themselves' in reference to the foundational conceptions of physics, mathematics, and logic. To reformulate the concept of 'essence' in terms of 'possibilities' in things, Mastrobisi considers ideas raised by Kant in *Metaphysical Principles of the Science of Nature* (1786) characterizing the concept of 'essence' by virtue of the 'possibility' (*Möglichkheit*) of the phenomenon that 'is presented / appears' in experience (in Husserl, bringing in essences in Cogito) and of the conditions that make it possible to access the experience.

Essence thus turns out to be "(…) the first inner principle of all that belongs to the possibility of a thing." (Kant, 2004, 3) Then, the external world (reality) and our vision will be two closely connected dimensions as we find ourselves in the experience of knowing the object (*Erlebnis*) given in transcendental Cogito. When an object (phenomenon) occurs in Cogito as an experience, the vision acquires a primary perceptual importance by accounting for the apprehension as a phenomenal object (*Erlebnis*). Faced with the phenomenon / object, intentionality permits access to its essence/s under the foundational possibility-conditions that account for the reality in experience.

Examples of unobservables constituted by essences in Cogito are: field, symmetry, energy, gravitation, quark, boson, graviton, etc. These are more or less conglomerate theoretical entities impregnated with multiple possibilities (for Neelamkavil, ontological universals pertaining to things / processes, guided by foundational universals) through which we can obtain knowledge, if the essence/s (Neelamkavil: connotative universals in Cogito) are accessed by eidetic reduction.

Thus, science is 'science of the possibilities of knowing'. Science in its search cannot access 'absolute truths' but can access the adjustments between possibilities (Neelamkavil: universals and foundational universals) and truths. Mastrobisi maintains: "(…) the science of nature is shown as a *science of the possibility* of knowing nature *in-sé* in the experience of the conditions of accessibility of nature, that is, as *a priori science of the possibility* of a mathematical natural science, the science of the method of scientifically determining nature on the basis of the data of experience." (Mastrobisi, 2015, 12)

What do these adjustments mean? Mastrobisi says: "(…) the category of possibility (*Möglichkeit*) in Kant expresses and comprises a particular type of relationship. (…) Kant had clarified the role of the category of modality: "«the categories of modality have in itself the particularity of not increasing minimally – regarding the determination of the object – the concept in which they are attributed as predicates, rather, it expresses *the relationship* with the faculty of knowing», that is, with the subject." (Mastrobisi, 2015, 12) Kant points out the relationship between possibility and knowing, within the subject who knows. Mastrobisi says:

> (…) the true Kantian *Copernican revolution* will not be consisted in the *relativized a priori* but in the new valuation attributed to the constitutive role, hence transcendental of the subject itself, that takes from the thing not the mere *Schein*, the simple appearance, but a particular *relationship* or *rapport* (*Verhältnis*) with oneself, coagulating in the *phenomenon* (*Erscheinung*)-*event* (*Er-eignis*). Thus, the Kantian-Husserlian relativity is assumed, which finds in the concept of *essence-possibility* and *object-phenomenon*, the fundamental instruments in the constitution of each possible rapport and re-composition of the separation between subject and reality. (Mastrobisi, 2015, 12)

His objective is to emphasize the role of possibility in the process of knowing through its relationship with Husserlian essences and reality. Under this vision, the Kantian modality categories account for three ways in which 'something' can be in time: at some indeterminate time (possibility), at a certain time (existence), and at all times (necessity). These categories of modality contribute nothing to the statement-content and refer only to the value of the copula in relation to thinking in general. In this way, possibility, existence, and necessity are modal categories and can be considered as logical, epistemological, and ontological categories.

Neelamkavil claims that all these are physical-ontologically facilitated in the categories of Extension-Change (Neelamkavil, 2018, 21-24, 36) because any reality necessarily existing 1) should exist non-vacuously, i.e., as Extended, as having parts, and 2) have Changing parts that finitely impact a finite number of other extended existents within and without. Extension-Change are thus the *Categories of* possibility, existence, and necessity in a real world.

Kant affirms that the categories of modality only express the relation with the faculty of knowing. "When the concept of a thing is already complete, I can still ask about this object, if it is merely possible or also real and, in the latter case, if it is also necessary." (CPR, 307, A219:B226). Therefore, the categories of modality do not express essential determinations of objects. They only determine the object in relation to the subject's faculty of knowledge. They are not real predicates.

Through these categories, no determination of the object is intended, it is only specified in what relationship the object is with the understanding and the empirical use of it, within the scope of possible experience. The categories of modality "(…) do not extend in the least the concept to which they serve as a predicate, but simply express the relationship of such concept with the cognitive faculty" (CPR, 307, A219:B266), and are limited to empirical use. The postulates put everything in relation to the knowing subject in general, that is, with the transcendental subject.

Thus, the postulate of possibility constitutes the first condition of 'thinkability' of every object. Kant: "Where do you want to derive the character of the possibility of an object that has been thought through an *a priori* synthetic concept, if not from a synthesis that constitutes the form of empirical knowledge of objects?" (CPR, 308, A220:B267) What makes an object possible is its conformity with the *a priori* forms of experience. So, we can know it independently of it, since we can know in advance some of what is possible. From what has been said, it is worth wondering if the possibility will not end up leading to reality.

One can think that 'real possibility' inevitably leads to reality. In fact, it must be concluded that there is nothing genuinely possible but what is real. Then, the communion between reality and possibility shows a dynamic and multiple character relating all objects, their manifestations, and the knowing subject. For Kant, the concept of possibility indicates the thing related to the intellect, while reality is a connection of the thing with perception.

Through the reconstruction of Kant's ideas, Mastrobisi accounts for reality in terms of the conditions of possibility, with experience being the fulcrum between both notions. From the reality-possibility relationship, objects emerge as 'objectivities' that science describes. In other words, Mastrobisi's phenomenological proposal maintains that each field of scientific research is made up of several structures of consciousness that can be studied through phenomenology. After an adequate clarification in reference to the dependence of the objectivities of the consciousness structures, the true 'possibility' can be determined without running the risk of becoming an object of this type (concept) for the consciousness alone. Following Husserl, Mastrobisi emphasizes that this type of fundamental science (phenomenology) goes beyond the factual and conceptual, since it can account for what is (and is not) possible in general terms. The beyond here are essences.

The reformulation of the Husserlian concept of essence through the reality-possibility-essence triad suggests the limitation of the notion on two sides: 1) connected to the subjective-absolute and objective-relative dichotomy and 2) as a redefinition of intersubjectivity due to the irreducibility between *Erleben* (experience) and *Erfassen* (understand) in the process of thinking the reality of things. In this way, the relativity of essences shows the existence of a possible consciousness-given form in a continuous process of clarification and redefinition of its objectivity and validity. (Husserl, 1992, 33-36) Mastrobisi calls this important process the intersubjective constitution of essences.

In this sense, how to link unobservables with Husserl's ideas and Mastrobisi's reformulation? In the previous sections was explained how Husserl does not limit intuition to sense perception showing the independence of the essential vision of the *hylé*. For its part, the reality-possibility-essence triad has communion with intersubjectivity in the constitution of essence. As a consequence of the reformulation that incorporates the trinomial relationship, the importance of the knowing subject is hinted at in the process of knowledge and multiplicity of possibilities of the phenomenon-object with reality.

The fundamental Laws of Conservation in physics find in Husserl's phenomenology a handle for access (through essential vision) towards understanding theoretical entities: how these are constituted through the intersubjective process of understanding and experience. As I have pointed out, unobservables (gravitation, energy, symmetry, quarks, etc.) are given in essences linked to the subjective-absolute and objective-relative duality to which we have access through the phenomenological method under the consideration of the multiple possibilities that previously condition the subject's experience within reality.

At this point it is convenient to point out that phenomenological linking of reality with the concrete experience of the individual must necessarily consider that the knowing subject does not refer only to what he directly perceives, but also to

what is 'objective' in theory experienced by any subject or community of subjects in which each subject is aware of herself simply as a fallible instance of the general knowledge process. From this viewpoint, all sensory objects are, as giving essence in the phenomenological procedure, only specific and possible ways of 'giving' to consciousness in a continuous intersubjective process of clarification and understanding of their totality and objectivity.

3.2. Extension-Change: Physical-Ontological Categories in Neelamkavil

Understanding the essences in Husserl requires going beyond the Aristotelian or later versions used for two millennia in the Western tradition in attempts to explain meaning and existence. Tradition has ontologically reified forms or made them purely conceptual. The conception of essences that we assume must be supported by non-reified and trans-mental forms in order for them to become rationally acceptable by being really capable of discussing 'Reality-in-total'.

For Neelamkavil, as I may interpret, Husserlian essences are abstract primordial forms, *Cogito*-level 'retentions', that (1) indirectly pertain to processual objects, (2) are produced from within any set of real empirical experiences, and (3) indeed are essential to every possible experience. In this sense, Husserlian essences in the *Cogito* are conceptual forms that reflect ontological universals from existent processes. Cogito-level essences have an appeal as the primordial pre-reflective experiential retentions because of their connection to ontological universals.

He points out at various contexts in his book (2018) that connotatively abstracted (i.e., Husserlian, Cogito-based) essences (forms of real and possible retentions) are the consciousness-based conceptual counterparts of universals that are more ontological than Cogito-level retentions. He calls these conceptual counterparts of real physical-ontological universals as 'connotative universals'. They collectively note and denote in Cogito the 'ways of being of processes' (Neelamkavil, 2018, 48, 64) that are 'out there' as ontological universals. (Neelamkavil, 2018, 48, 64) The latter are not in Cogito.

The ways of being of processes are ontological universals since they must be treated as objects insofar as they are ontological, and they are considered real because they belong to existing processes. However, as they are the forms of being of processes, they do not exist. Hence, ontological universals are the multiple possibilities of the multifarious layers of phenomena in the multifarious layers of Reality-in-total.

For Neelamkavil, entities are always Extension-Change processes. Ontological universals, as forms of being of continuous dynamic processes, are Extension-Change expressions. Within the phenomenological framework, there are multiple possibilities of appearance in phenomenal reality (from existents and forms pertaining to them) of phenomenon-objects (physical existents). When we 'know' an object, it is apprehended by the subject in terms of Cogito-level essences, which are from the anterior fulfillments of the possibility in one of its multiple facets. These multiple possibilities are ways of being of processes in Extension-Change. Neelamkavil summarizes the above:

> (…) anything exists as extended-changing in terms of transfer of impact elements within and to each other finitely in finite time, every iota in physical existents is permanently in Extension-Change as such, and therefore exists causing effects within and without, all finitely in finite time, which fact again shows that causal processuality is irreducibly Extension-Change. The constant causal togetherness of some processes with a finite or infinite amount of stability in activity is Process. A process is an existent in such togetherness. (Neelamkavil, 2018, 47)

Within the multiplicity of possibilities (ontological universals) of a phenomenon-object that is a permanent process of Extension-Change, intersubjectivity in a continuous process of clarification / understanding (i.e., theory) of Reality-in-total becomes the systematization of Cogito-level essences *about reality*. Essences are variously vague – but idealized as unchanging – Cogito-level reflections of ontological universals that exhibit processuality in Extension-Change. Essences, understood as connotative universals, refer within the continuous process of intersubjectivity to the processual counterparts in the world. This is always based on systematic consciousness (reflection) of ontological universals in Cogito.

Hence, theory (intersubjective understanding of processes or Reality as such) transpires only through observables (processes: mountain, galaxy, etc.), theoretical entities (absolute unobservables that are characteristics of processes), chains of theoretical entities (centrifugal force, potential energy, symmetry, etc.), and partial unobservables (processes like field, gravitation, election, quark, boson etc.). The latter are strictly what physics calls unobservables.

Theoretical entities and unobservables possess a body of ontological universals mixed in the Cogito with essences and systematized. They are a complex of both. This is the principle of knowledge in physical-phenomenological realism. Complex theoretical entities and unobservables, when characterizable by Extension-Change, denote existents. Here begins what I term 'phenomenological scientific realism'. Partial unobservables – if proved as existent in the course of history by intersubjective verifications – are processes such as gravitation, quark, field, boson, etc. Until being proved intersubjectively, partial unobservables are made up of systems of essences within the Cogito, with less correspondence with systems of respective ontological universals of processes. For example, gravitational waves have lately been observed experimentally. The existence of graviton as wavicle is theoretically concludable from this. Hence, 'gravitons' have some verity. They are now partial unobservables.

Intersubjectivity coupling Cogito-level essences with the ontological universals of processes ever better is the process of experimental proofs about phenomena and data derived from phenomena. If what are so far termed partial unobservables become scientifically acceptable entities, they are and have been processes under the categories of Extension-Change, since anything existent is in Extension-Change. This is also the Principle of Universal Causality: "(…) any group/s of multiple events are in the extended-changing / processual togetherness, where causation means that each near-infinitesimal part of matter-energy is the process of projection of impact elements to many other such." (Neelamkavil, 2018, 21) Hence, the way of proving the existence of an unobservable is inevitably causal.

We think and experience existent processes. We are embedded within Reality and its ideal truths. Ontological universals of processual objects outside consciousness are 'ways of being' of processes. (Neelamkavil 2018, 45) They are primarily in Reality, and secondly as essences / connotatives in Cogito. Ontological universals are therefore the ontological counterparts of Husserl's essences. The primal conditions behind existents, universals, and essences are Extension-Change. The multiple possibilities, namely, ontological universals (ways of being) are real out there, but without existence. They are the ontological conditions of the rapport of processes with the faculty of knowing. Essences are the epistemic conditions of the rapport of 'giving-itself' in phenomena with knowing.

Essences (connotative universals / retentions of ontological universals) are real only within *Cogito* in its retentions of universals. Just as space-time are the most important (Kant and Husserl), and therefore categorial, of retentions / essences at the *Cogito* level, their metaphysically categorial counterparts are Extension-Change. Extension-Change are the most general ways of being (ontological universals) of existent processes. They are ontologically in processes, real but non-existent. Space-time are not in processes, but in Cogito!

Extension-Change are definable with respect to the cosmos: Extension is the abstract ontological nature of "having multiple parts" in existents. Those without parts do not exist. 'Space' is epistemically the measure of the abstract state of having finite parts with respect to a stipulation. Change is the abstract ontological nature of the formation of finite impacts of parts on other parts inside and/or outside. 'Time' is epistemically the measure of formation of the impact with respect to a stipulation. (Neelamkavil, 2018, 21)

Space-time are epistemic conditions, pure *a priori* forms that epistemically make knowledge possible. (Neelamkavil, 2018, 54) They cannot directly show the continuous dynamics of the multiple possibilities of physical processes based on Extension-Change. The latter are understood together, not separately. They represent the most intimate and universal constitution of all non-empty processes.

The Husserlian conception of essences needs the metaphysical categories of Neelamkavil to account for existents. Scientists' distrustful gaze towards Husserl's methodology is largely due to their misunderstanding of his Cogito-based notions, postulates, and complex language. Through the above treatment of the problem of partial unobservables and theoretical entities, the necessity of a renewal in Husserl's phenomenological vision is demonstrated. By reformulating some of its key elements and incorporating the essential categorial universals (Extension-Change), the processual aspect of existents is brought into the realm of intersubjectivity. It entails the constitution of essences in Cogito as well as the consideration of entities as continuous processes of Extension-Change.

I go further from this. Weyl's suggestion to access the invariable aspects of all existence is realized by the metaphysical categories of Extension-Change. These invariants are the ontological symmetries in all physical existents. Physical symmetries are a subclass of Extension-Change processuality. All symmetries must undergo the test of Extension-Change and universals for their realization in Reality.

These two categories have the capacity to exhaust all existing ones and their metaphysical nature. To study real existent objects and objects pertaining to them, the point of view of their Extension-Change existence, origin, and evolution are necessary. This supports the ontological position involving all real objects, including ontological universals and connotative essences.

Thus, we have a broad spectrum of "entities" based on observability. At the one end are gross physical processes. More micro and astronomical entities follow. Observationally far-fetched entities follow next. Then at the farther end appear theoretically postulated entities necessitated by the success of some theories. But all are universal-laden. Entities not absolutely laden with conceptual essences and supported slightly by out-there ontological universals follow next. Towards the end of the spectrum are ontological universals (pure theoretical entities) and then at the rear extreme are merely conceptual essences that can be imaginary when absolutely laden by conceptual essences at Cogito and not at all by ontological universals.

Now the conclusions: Space-time are Husserlian epistemic essences, cognitive conditions, mathematically theoretical entities, and are not in processes. Processes are not in them. No existent process is in Einstein's epistemically mathematical, four-dimensional space-time. Mathematical equations of space-time in physics and cosmology are, ontologically, equations based on Extension-Change (existence conditions). Existent processes alone have the essential nature of being in Extension-Change. These two categories are *metaphysically real* in existents. Space-time are not metaphysically real in existents, but epistemically real in Husserlian *Cogito*. Methodologically, thus, Husserlian essences remain useful for physics.

Gravitational densities, said to curve the four-dimensional epistemic space-time, better be mathematized as curving four-dimensional ontological Extension-Change regions. Extension-Change are the ontological forms of Husserlian (connotative) essences, hence of space-time as the essences of preconceptual retentions in *Cogito.* Confinement to *Cogito*-level space-time description limits science and philosophy to a method of thought without sufficient right to speak of existent processes. Hence the reason for the distrust of phenomenology by some scientists, and for the need to revise the metaphysical foundations of physical theories, especially of Relativity.

4. References

Aguirre-García, J. C. (2014). "Husserl y el Antirrealismo (¿o Realismo?) Cientifico". In *Kriterión*, No. 129: 287-308.

Bernet, R. (2004). "Husserl's Transcendent Idealism Revisited". In *The New Yearbook for Phenomenology and Phenomenological Philosophy*, vol. IV: 1-20.

Boscovich, R. (1922). *A Theory of Natural Philosophy*. Chicago: Open Court.

Bridgman, P. W. (1985). *La concepción operacionalista de las teorías físicas*. Caracas: Universidad Central de Venezuela Ediciones.

Carman, C. C. (2016). "Realismo Científico". In *Diccionario Interdisciplinar Austral*. C. E. Vanney, I. Silva & J. F. Franck (eds.). URL: http://dia.austral.edu.ar/Realismo_científico [Online].

Carnap, R. (1936). "Testabilidad y significado". In *Filosofía de la ciencia*, 3 (4): 419–471. doi: 10.1086/286432

—— (1939). *Fundamentos de lógica y matemáticas*. Chicago: University of Chicago Press.

—— (1950). "Empirismo, semántica y ontología". In *Revue Internationale de Philosophie*, 4: 20–40.

—— (1956). "El carácter metodológico de los conceptos teóricos". In *Minnesota Studies in the Philosophy of Science I*. H. Feigl & M. Scriven (eds.). Minneapolis: University of Minnesota Press, 38-76.

—— (1961). "Sobre el uso de Hilbert ε-operator in Scientific Theories". In *Ensayos sobre los fundamentos de las matemáticas*. Y. Bar-Hillel, E. I. J. Poznanski, M. O. Rabin & A. Robinson (eds.). Jerusalem: Magnes Press, 156-164.

—— (1966). *Fundamentación lógica de la física*. Néstor Miguens (trans.). Buenos Aires: Sudamericana.

Chakravartty, A. (2007). *A Metaphysics for Scientific Realism. Knowing the Unobservable*. Cambridge: Cambridge University Press.

Duhem, P. (1991). *El objetivo y la estructura de la teoría física*. P. P. Wiener (trans.). Princeton: Princeton University Press.

Einstein, A. (1980). *Mi visión de Mundo*. S. Gallardo & M. Bübeck (trans.). Titivillus [e-book online].

Fine, A. (1986). *The Shaky Game: Einstein, Realism, and the Quantum Theory*. Chicago: University of Chicago Press.

Feyerabend, P. K. (1962). "Explanation, Reduction, and Empiricism". In *Minnesota Studies in the Philosophy of Science, Vol. 3*. H. Feigl & G. Maxwell (eds.). Minneapolis: University of Minnesota Press, 28 –97.

Jaramillo Uribe, J. M. (2014). "Realismo Estructural y Estructuralismo Metateórico". In *Estudios de Filosofía*, No. 50, Julio-Diciembre, 171-193.

Heffernan, G. (2009). "On Husserl's Remark that "[s]elbst eine sich als apodiktisch ausgebende Evidenz kann sich als Täuschung enthüllen …" (XVII 164: 32–33): Does the Phenomenological Method Yield Any Epistemic Infallibility?" In *Husserl Studies* 25: 15-43.

Husserl, E. (2013). *Ideas relativas a una fenomenología pura y una filosofía fenomenológica. Introducción + Libro Primero: Introducción general a la fenomenología pura*. A. Zirión Quijano (trans.). México: UNAM / FCE.

___ (2006). *Investigaciones Lógicas 1*. M. G. Morente y J. Gaos (trans.). Madrid: Alianza.

___ (1999). *Cartesian Meditations: An Introduction to Phenomenology*. (trans.) D. Cairns. Dordrecht: Kluwer.

___ (1986). *Meditaciones cartesianas*. J. Gaos y M. García-Baró (trans.). México: FCE.

___ (1982 a). *Ideas Pertaining to a Pure Phenomenology and to a Phenomenological Philosophy*. *First Book. General Introduction to a Pure Phenomenology*. F. Kersten (trans.). Boston: Martinus Nijhoff.

___ (1982 b). *La idea de la fenomenología. Cinco lecciones*. M. García-Baró (trans.). Buenos Aires: FCE.

___ (1982 c). *Logical Investigations I*. J. N. Findlay (trans.). New York: Routledge.

Kant, I. (2004). *Metaphysical Foundations of Natural Science*. M. Friedman (trans., ed). Cambridge: Cambridge University Press.

___ (2007). *Crítica de la razón pura*. Buenos Aires: Ediciones Cohhue.

Mastrobisi, G. J. (2015). *Fenomenologia e Relatività: Studio su possibilità ed essenza nella fisica contemporanea*. Roma: Stamen.

___ (2018). "Phenomenology and Relativity: Husserl. Weyl, Einstein and the Concept of Essence". In *Abordagem Gestalt* [online], Vol. 24, n.3: 358-365.

___ (2019). "Why Relativity needs Phenomenology? Eidetic-Relativistic Kinesthetics and Temporality in Husserl, Weyl and Einstein". In *Aoristo*, vol. 1, n. 4: 140-172.

Maxwell, G. (1989). "El estado ontológico de las entidades teóricas". Olivé, L., & Pérez Ransanz, A. R. (eds.). In *Filosofía de la Ciencia: Teoría y Observacíon*. Cdad De México: Siglo Veintiuno. 116-144.

McMullin, E. (2002). "The Origins of the Field Concept in Physics". In *Physics in Perspective* 3: 13-39.

Neelamkavil, R. (2015). *Physics without Metaphysics?* Frankfurt: Peter Lang.

___ (2018). *Gravitational Coalescence Paradox and Cosmogenetic Causality in Quantum Astrophysical Cosmology*. Berlin: Peter Lang.

Salmon, W. C. (1997). *Causality and Explanation*. Oxford: Oxford University Press.

Van Fraassen, B. C. (1980). *The Scientific Image*. Oxford: Clarendon Press.

Weyl, H. (2009). *Mind and Nature: Selected Writings on Philosophy, Mathematics, and Physics*. P. Pesic (ed.). Princeton: Princeton University Press.