Science and the Lebenswelt on Husserl's Philosophy of Science

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Abstract: I here present and discuss Husserl's clarification of the genesis of modern empirical science, particularly its mathematical methods, as presented in his last work, *The Crisis of European Sciences and Transcendental Phenomenology.* Although Husserl's analyses have as their goal to redirect science to the lifeworld and to reposition man and his immediate experiences at the foundation of the scientific project so as to overcome the "crisis" of science, I approach them from a different perspective. The problem that interests me here is the applicability of mathematics in empirical science, to assess Husserl's treatment of this issue in order to see if it can be sustained from a strictly scientific point of view regardless of philosophical adequacy. My conclusion is that it cannot. What Husserl takes as the "crisis" of science is inherent to the best scientific methodology.

Keywords: Mathematized science, Husserl, Lebenswelt, The crisis of science, The applicability of mathematics.

The lifeworld is not free of science, for science, after all, is part of life. Experimentation and testing of scientific hypotheses and theories, for example, to the extent that they ultimately rest on sensorial perception, either naked or instrumentally enhanced, are not essentially different from the prosaic activities of the lifeworld, such as feeling the texture of a fabric or checking a piece of information. Yet, although perception pertains to the lifeworld, the scientific *interpretation* of perception does not. Experimental data, which are never *mathematically* precise (no one will ever read the value of, say, π on a scale) are for scientific purposes often interpreted as *approximations* to the "real" values of the physical magnitudes being measured, which the *theory* tells us to expect (for example, π).

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All sorts of vicissitudes are thought to stand in the way of exactness, the deficiencies of human attention, the inaccuracy of sensorial perception, unforeseeable local fluctuations of relevant parameters, in short, "errors" of all sorts. The experimental scientist, then, inhabits two different worlds, the lifeworld and the world of science; he perceives as a man of the lifeworld but interprets his perceptions with the idealized scientific picture of empirical reality firmly rooted in his mind. He is convinced that despite his efforts empirical reality will *never* disclose itself adequately to the senses; no matter how much his sensibility is enhanced by scientific instruments or how careful he carries out his measurements. *Le tourbillon de la vie* will always interfere.

The lifeworld is the world of the "*a peu près*", but exactness prevails in the purified, pristine world of science. A cannonball follows a trajectory *perfectly* determined by a quadratic function, space is filled by an electromagnetic field *precisely* determined at each point, the metric of space-time is *unambiguously* given by some differential form, etc., etc. Behind the stage where life happens there lies, or so science presupposes, a hidden structure of mathematical precision. But science is interested in the hidden structure, not the drama happening on stage. From the perspective of science, the reality accessible to the senses is a more or less deceptive manifestation of the true reality that will remain forever hidden to the senses. Thereby, as a matter of *principle*, not mere fact, the senses are necessarily impotent to reach real reality in an adequate and apodictic manner.

Husserl saw a problem here. It is a basic tenet of empiricism, to which science pledges allegiance, that scientific theorizing must be confronted with experience and that in experience alone it can be validated. But scientific experimentation, no matter how refined, is basically and ultimately touching, seeing, smelling, tasting and hearing; the scientist must eventually use his eyes to check to which number in a numerical scale the pointer is indicating (or better, within which more or less fuzzy range of the scale the pointer is located). But if sensorial perception is *a priori* disqualified as a provider of adequate knowledge, is not science *a priori* undervaluing the validation it seeks? What is the *point* of empirical testing? Moreover, by alienating the world as man experiences it is science not *ipso facto* alienating man? Husserl answers both questions affirmatively. He concluded that modern science is, and has from its beginning been immersed in a "crisis" characterized by the alienation of man and all that makes sense to him. This "crisis", as Husserl saw it, poses problems for philosophy and culture in general, including, as we will see, understanding the scientific project itself.

I will be more explicit below; at this point, I only want to show what direction Husserl believed a way out of this critical situation (which is in fact a crisis of man) could be found. It is important to keep clear, however, that, for Husserl, the crisis of science is not a crisis *internal* to science. Scientific methodology is a scientific affair; philosophy has nothing *scientifically* relevant to say about it. Philosophy's job is not "to fix" science but to understand it, disclose its true nature and clarify its methods (which include the mathematization that characterizes modern science since the times of Galileo)[1] Phenomenological clarification is, for Husserl, the first step in solving the crisis of science.

To accomplish this, Husserl embarked on a journey in search of the origins of modern science. This meant first and foremost the investigation of the intentional genesis of the scientific conception of empirical reality, "unpacking" its many layers of sedimented meaning so its true nature can be brought to light. What is finally revealed is that empirical reality as conceived by science is not *real* reality, only an intentionally elaborated idealization of the sole true reality, that perceived through the senses, devised for methodological purposes. For Husserl, our modern mathematical science of nature deals with reality as perceived (the only true reality) by dealing with a symbolic-mathematical surrogate of it.

Husserl also detected a tendency to "forget" that goes along with the bestowing and sedimentation of intentional meaning, which obliterates intentional constitution and takes as given what is only a product. Eventually, a reversal of ontological and epistemological priorities takes place, the *originally given* empirical reality, that which is experienced with the senses, losing its status of true reality and being substituted as such by a mathematically purified surrogate. The world of science where the immediate sensorial perception of man is degraded as "rough" and "imperfect" becomes the real world. Thus science "naïvely" embraces Platonism as its "official" philosophy. Husserl believed that the right order of priority had to be reestablished if the crisis of science was to be solved; that the mathematical world of science must be "unmasked" as a product of intentional action devised for methodological purposes and the world experienced through the senses restored to the dignity of the true real world.[2] This required, in particular, that the idealizations and presuppositions that go into the intentional constitution of the world of science be brought to light, a task carried out in full in the first sections of *Crisis*.

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[1] This is also true in the philosophy of mathematics, whose task is to clarify not rectify.

[2] In connection with this it is instructive to mention what the 1952 Nobel Prize winner Felix Bloch (Bloch 1976) had to tell about a conversation he had with Werner Heisenberg, of whom he had been the first

The world, however, is not only what we (or a generic I) *have* actually experienced, it also contains what *can* in principle be experienced. The horizon of possible experiences beyond experienced reality, however, or so Husserl thinks, is not a closed totality already completely determined in itself. *This is a presupposition of science, not of the man of the world*.[1] But, and this is, I believe, very important, it is *only* by presupposing this that science can accomplish the task it imposed upon itself of *anticipating* experience beyond the possibilities of rough anticipation available in the lifeworld.

One aspect of Husserl's clarification interests me particularly. By revealing the true nature of empirical reality as conceived by science, Husserl made comprehensible the apparent "mystery" involving the applicability of mathematics in the empirical science. He has clearly shown *how* such a thing is *possible* (although not so much how it *works*), that the empirical science of nature can be mathematized because empirical reality *as conceived by science* is already mathematical. Not the actual reality experienced through the senses (not to the extent required by science anyway), but the scientific image of it, a mathematically improved version of our perceptual "first draft" of reality. Galileo told us that the book of nature is written in mathematical characters and cannot be understood by those who are not conversant with mathematics. This remains strictly true. What Husserl has shown is that this book is not a *picture of* nature, but a *novel about* nature. It tells a fictitious tale from which we can, nonetheless, infer important things about the world as experienced by us. This imposes upon the philosopher of science the task of investigating how and why this book was written and its narrative resources if he wants to understand why and how it can tell anything about the reality we experience through the senses and, more importantly, why it is so *efficient* at that.

The transcendental history of empirical science is the history of its intentional constitution. This is a job for phenomenology (to which the initial part of *Crisis*, essentially chapter II, particularly §9, is dedicated), but cannot be done without the assistance

doctorate student: "We were on a walk and somehow began to talk about space. I had just read Weyl's book *Space, Time and Matter*, and under its influence was proud to declare that space was simply the field of linear operations. "Nonsense," said Heisenberg, "space is blue and birds fly through it." This may sound naive, but I knew him well enough by that time to fully understand the rebuke. What he meant was that it was dangerous for a physicist to describe Nature in terms of idealized abstractions too far removed from the evidence of actual observation. In fact, it was just by avoiding this danger in the previous description of atomic phenomena that he was able to arrive at his great creation of quantum mechanics." Husserl would certainly take side with Heisenberg.

[1] But it is by presupposing this that science can make unrestricted use of classical logic, the principle of bivalence (or excluded middle) in particular (see da Silva, 2013).

of factual history (which, however, Husserl barely touches upon).[1] Science has to do with sense-formations which have a (transcendental) history that requires phenomenological clarification. As I have already mentioned, Husserl's strategy for clarifying the sense-formation "empirical nature" consisted in working his way back through layers of sedimented sense, "desedimenting" them so as to bring to light the intentional action that went into its constitution, eventually revealing the source from where sense originally emanated. At the end of the journey, Husserl finds the lifeworld, which, reversing scientific ontological priorities, he reestablishes as the original reality and the primary source of meaning. Thus, he thinks, the epistemological dignity of experience is reinstalled and coherence in the empiricist allegiances of science restored.

The crisis of science, Husserl believed, was not confined to science; it spread to philosophy and psychology, blocking the way to a truly philosophical universal science whose foundations, Husserl insisted, must be firmly rooted in the lifeworld. Descartes, the philosopher who took mathematical extension as the essence of the physical body, borrowed from mathematics the criterion of truth, advocated a mathematical methodology for reasoning, and, more importantly, conceived the idea of a *mathematical scientia universalis*, is a perfect example of the new philosophical *Zeitgeist* that "contaminated" modern philosophy. Descartes' philosophy and that of those who followed him, Husserl claimed, would be impossible without Galileo's conception of reality as a closed mathematical manifold, a "rational unified system" (Husserl, 1970: §11). To overcome the critical alienation situation in which science, philosophy, and man are immersed, Husserl proposed a return to the lifeworld, the source where sense originally flows.

But, again, the search for the origins of modern science, the careful investigation of the intentional constitution of scientific sense-formations, the clarification of scientific methods, and the re-establishment of the ontological and epistemological dignity of the lifeworld is not to be carried out *against* science, for nothing is *wrong* with it or its methodological strategies. Nonetheless, if the ties of science with the lifeworld are not repaired, Husserl believed, science risks being incomprehensible, even absurd. Only by

[1] The transcendental history of modern physics is intertwined with that of mathematics, which plays such a pivotal role in it. Modern physics, with its characteristic sense, could not have been constituted independently of the shift of sense that accompanied the creation of Greek geometry. An investigation of the intentional genesis of geometry and its objects was carried out by Husserl in his essay "The Origins of Geometry", which appears as an appendix in W. Biemel's edition of *Crisis*. Jacob Klein (Klein, 1992) has argued that the task would not be complete without a similar investigation concerning the concept of number (about this see Hopkins, 2011).

reestablishing "*de jure*" ontological and epistemological priorities, he thought, could science make sense, its methods and fundamental hypotheses clarified and circumscribed, and its criteria of validation firmly secured. So, although the development of a fully articulated philosophy of science was not its primary goal, *Crisis* contains the most articulate reflection on scientific issues on Husserl's part (at least as far as the physical sciences are concerned). I here want to examine it more attentively, to verify the extent to which it enlightens us about the nature of science and its methods, but also its shortcomings, the extent to which Husserl's struggle to safeguard man from alienation can jeopardize the effectiveness of science and the accomplishment of its task.

Crisis begins with a detailed historical account of the genesis of modern (seventeenth century) physical science, whose characteristic trait is *mathematization*. For Husserl, the spirit of the new science was born in ancient Greece, where eastern geometry, essentially a technology pertaining to the lifeworld, was completely redefined as the science of an idealized rational domain of *becoming* (geometric *constructions*). Galileo promoted the same radical shift of sense concerning empirical reality, pushing it a little further. Besides conceiving empirical reality as an ideal, mathematized domain of *being* (not *becoming*) he also posited it as existing and completely determined *in itself*. Thus, Husserl thought, the germ of a crisis was instilled in science. The consequences were many, the downgrading of perception as the privileged means of access to empirical reality, the opening of doors to symbolization and symbolic manipulations, sometimes carried out in complete disregard for what the symbols meant (which Husserl called "technization"), the refusal to grant objective status to certain perceptual aspects of things (colors, for example, are no longer seen as objective properties of bodies, but subjective impressions caused by light of determinate frequency reflecting on the body's surface and falling on our retinas, with no *objective* reality), in short, the alienation of man from his living experience and all that makes sense to him.

A very important aspect of modern science, as Husserl clearly saw, is the mathematization that characterizes it. Concerning this, two questions immediately impose themselves: 1) How is it possible that mathematics has *anything* to say about empirical reality? 2) How is it possible that mathematics is scientifically so *effective*? We can easily extract from Husserl's considerations a *correct* answer to (1), but, unfortunately, he does not have anything to say about (2). More than anything, Husserl *worried* about the intromission of mathematics, particularly purely symbolic mathematics, in empirical science, for it could lead to alienation. His goal was to place man in control again, not investigate the scientific usefulness of mathematics (although his recipe for avoiding man's alienation also serves the purpose of making it impossible for technization to lead scientific methodology astray – at a price though, for the "blind" use of meaningless symbols has an important *heuristic* role in science). If the sense sedimented in routine scientific practices, concepts and methods could be, at least in principle, reactivated, he thought, man would once more be in charge, and shifts of sense, particularly those that symbolization could induce, would be avoided.

Husserl also wanted to regain the lifeworld for science, which, of course, could not be a mathematical science. He stood *against* mathematization being seen as the distinctive trait of scientificity. This went along with a somewhat critical disposition concerning the role of mathematics even in empirical science. Since the lifeworld is the real world and the world of science a construct devised for methodological purposes, mathematical methods must be carefully circumscribed so as to prevent science from alienating itself from reality. The important question, however, is whether this is, *from a strictly scientific perspective*, desirable. I believe that it is not, that Husserl's re-installment of the lifeworld as the sole source of meaning in science translates into the requirement that *each* scientific proposition must *individually* express the idealization of a possible experience. This requirement does not correspond to the methodological practices of science and would, if enforced, seriously jeopardize their effectiveness. Science *must* alienate the living reality of man so as to accomplish its task.[1] I will come back to this later; for now, let us spend some time with Husserl.

For him, as I have already noted, although the crisis of science was intensified by the creation of the modern mathematical science of nature from the seventeenth century on, its origins can be traced back to the ancient Greeks. However, Husserl claimed, despite the idealization and systematization (i.e. axiomatization) that geometry knew in the

[1] To make clear what I have in mind, let me give an example. The complex-valued wave function of quantum mechanics does not correspond to a real wave or, directly, to anything in the world. According to the standard Copenhagen interpretation, only the square of the modulus of the wave function has some physical meaning, namely, a probability density, which, by the way, is hardly a purely physical entity. In a sense, the wave function "codifies" in mathematical form all the relevant information about a physical system, information we can "extract" whenever we want. As the great mathematician and physicist (and part time philosopher) Hermann Weyl claimed, physical theories, together with their heavy mathematical apparatus, are symbolic constructions that touch reality only at few points, but that must, then, "check". If they do not, the *entire* theory, together with its mathematics (and maybe even its underlying logic), must be reexamined and fixed. The relations of science with reality are more subtle and, we could say, more superficial than Husserl believed necessary to rescue man from the situation of alienation vis-à-vis the world that science impinged on him.

hands of the Greeks (from Tales to Euclid), they never believed that the geometrical domain was a closed one completely determined in itself where facts subsisted *sub specie aeternitatis*, waiting only to be revealed; a domain in which "everything that ideally 'exists' in the geometrical space is from the start already univocally decided in all its determinations. Our apodictic thinking only 'discovers', in its infinite progression, stepwise, according to concepts, principles, reasoning and proofs, what from the start, in itself, truly already is" (Husserl, 1970: §9). For Greek geometers, geometry had to do with ideal possibilities of constructions, with becoming, not being (despite Plato's interpretation).

Modern geometry, contrary to ancient geometry, however, conceives its domain as a "rational infinite domain of being systematically mastered by a rational science" (Husserl, 1970: §8), "an infinite world, closed in itself, of ideal objectivities presenting itself as a field of investigation" (Husserl, 1970: §9). How such a conception came about, the idealizations and presuppositions it harbors is the theme of Husserl's essay *The Origins of Geometry*, which sets a model for works in transcendental history.

The distinctive trait of Galilean physics is the mathematization (rather, geometrization) of empirical reality, and its most basic presupposition is that empirical nature is a mathematical *Universum* in the geometrical sense, i.e. an infinite realm of mathematical idealities closed and completely determined in itself into which mathematics only has access (Galileo's famous "the book of nature is written in geometrical characters..."). Nature is geometric, and only geometry has adequate access to the secrets of nature. In this *Universum*, moreover, all co-beings are submitted to the omnipresent legality of a universal causal regulation.[1] To the question "how is it possible 'to know the world philosophically', that is, in a seriously scientific manner, [building] systematically, in some way *a priori*, the world, the infinity of its causalities, from a meager stock of what is possible to establish in direct and relative experience?" (Husserl, 1970: §9), mathematics seems to provide the answer. By conceiving empirical reality as a geometrical *Universum*, modern science treats nature like but not *exactly* like geometry treats the geometrical domain. The difference, which Husserl is careful to point out, is that whereas geometry is able to reach for the legality subjacent in the geometric realm *a priori* and once and for

[1] Has the collapse of the "classical" conception of causality brought about by quantum mechanics changed this picture in some way? According to Husserl, it did not. In quantum mechanics, nature is still "mathematical in itself, given in formulas and interpretable only in formulas" (Husserl, 1970: §9). Moreover, causality is not completely eliminated in quantum mechanics, since the "state" of a system at any given point in time still strictly depends on its state at any previous instant, the "state evolution" being mathematically regulated.

all, science can only rely on the meager stock of experience and so can never touch the mathematical legality that supposedly lies within the core of empirical reality in a completely satisfactory manner. Why is it so difficult to extract from nature its mathematical structure? Why can we not have access to it as we have to the structure of the geometrical realm? I will come back to this later, but I can already reveal what I think Husserl's answer was: in fact, mathematics is *not* in nature (as we perceive nature), not at least to the extent that science presupposes; mathematics is *only* in our scientific dealings with nature. So, the mathematical structuring science imposes on our perception of nature must be determined in conformity with the data of perception (and as scientific imagination deems appropriate), not *a priori* and definitely not once and for all, since the field of perception has an open horizon.[1]

Husserl's search for the sources of science, as I have previously mentioned, involves uncovering hidden presuppositions which, by remaining hidden, make it difficult, if not impossible, to correctly understand scientific methodology and draw its limits of jurisdiction. Let us consider one, related to the mathematization of secondary qualities, such as color, texture, etc. Modern science is well-known for "subjectifying" them, which can only be recovered objectively by indirect means. *As such*, secondary qualities belong to the realm of the subjective-relative that is of no concern for science but can be recovered *as something else* in the objective-absolute (that is, valid for all) realm of science. For example, the subjective sensation of color can, for scientific purposes, be replaced by the wavelength (or frequency) of the radiation that "produces" the color sensation. This, however, Husserl says, presupposes that "the specifically sensible qualities (the 'content') experienceable in the bodies given to intuition *be intimately connected* [one to another] *according to a rule* and, in a very particular way, to *forms* that belong to them according to their essence" (Husserl, 1970: §9). The mathematization of secondary qualities, then, requires that sensible, intuitive "contents" be related with strict legality not only to one another but also to mathematical forms, which can act as objective substitutes of them. But this, Husserl observes, does not go by itself. Despite the evidences the Pythagoreans have already brought to light, this is a *presupposition*, a *hypothesis*, justifiable only by

[1] Mathematical domains are subsumed to *concepts*, and it is by inquiring their sense that mathematics can theoretically master them *a priori* and once and for all. The concept of nature, on the other hand, cannot serve the same purpose; empirical science is then constrained to investigate its extension so as to master it theoretically.

the Galilean belief in a *Universum où tout se tient* and whose internal connections can only be explicitly rendered mathematically.

Once intuitable contents are replaced by mathematical entities (numbers and the like), the covariance of intuitable contents *experienced* in the lifeworld can, under the hypothesis of strict underlying legality, be mathematically expressed in *formulae* involving only the mathematical representatives of experienceable contents. These formulae are then mathematical expressions of *natural laws* on whose basis *intuitions* can be anticipated. Mathematics now *controls* the lifeworld. According to Husserl, "the indirect mathematization of the world, which expresses itself as a methodic objectivation of the world of intuition, produces general numerical formulae which, once found, can serve in applications to accomplish the objectification of singular cases subjected to them. The formulae express general causal connections, 'laws of nature', laws of real dependence, under the form of 'functional' dependence among numbers" (Husserl, 1970: §9).

What sort of hypothesis is this, that nature is subjected to strict and mathematically expressible legality? Is the *fact* of science and its unquestionable success a confirmation of this "Galilean" hypothesis? According to Husserl, this is "a very surprising hypothesis indeed. Our empirical science, which has for centuries been its confirmation, is thus a confirmation of a very surprising nature. *The surprising thing is that the hypothesis remains, despite its confirmation, always and ever a hypothesis*. Its confirmation (the only conceivable for it) is an infinite succession of confirmations" (Husserl, 1970: §9). Galilean science, Husserl thought, is founded on a "hypothesis" that cannot be either confirmed or disconfirmed, which makes it a rather peculiar hypothesis. This demands an explanation.

Could it not be that the "hypotheses" that nature is a domain existing and completely determined in itself submitted to strict legality, which mathematics can only adequately express, be given a "positivist" reading? Such as, for instance, the Copernican heliocentric "hypothesis", which can be seen as a mathematical scheme "to save the phenomena" with no consequence for reality as it *really* is, a view the Church pressed on Galileo, but that Galileo refused? (According to historians of science, such as Koyré and Crombie, Galileo was definitely not a "positivist"; mathematics was not, for him, an instrument for conveniently structuring the *phenomena*, but was built in the structure of nature *itself*). Could Husserl be ranged with the "positivists"? Was mathematization, for Husserl, only a way of structuring our *experience* of reality while reality *itself* remained inaccessible?

Such an interpretation, I believe, is completely alien to Husserl's thought. It would require a distinction between noumenal and phenomenal realities, with phenomenal reality, and it alone being given, for reasons of convenience, a mathematical structure. This mixture of Kantianism with pragmatism has no place in his philosophy. Husserl's distinction is not between phenomenal and noumenal realities, but between the lifeworld and what science takes for the real world. Our experience of reality, he thinks, is definitely *not-mathematical* or at least not mathematical in the same sense as scientific reality is and can only be mathematized in the molds of science by being idealized, that is, by being put out of reach of experience. The reality we experience through our senses, however, Husserl claims, is reality *itself*, the only real one. Mathematized reality, on the other hand, is only an idealization of reality, not in a metaphysically serious sense *real*. So, for him, there is no distinction between reality itself and experienced reality: what we experience *is* reality itself. Mathematized reality is neither reality itself nor experienced reality, only an ideal model of *experienceable* reality devised for methodological purposes.

Although science depends on the presupposition that nature is submitted to laws, natural laws do not necessarily follow, at least not completely, from the concept of nature; they have to be read *in the phenomena*. In nature, however, the realm of the actually experienced is *constantly* open to the horizon of the still to be experienced. Unlike mathematical domains which are in *stricto sensu* capable of being completely surveyed *a priori*, those of science cannot. Empirical science, then, must always be ready to be shaken by what experience may bring; the legality reigning in nature must be constantly redesigned and re-established. Hence, the foundational "hypothesis" of science cannot ever be definitively either confirmed or refuted. The conclusion then offers itself; this, in fact, is not an *empirical* hypothesis, but a *transcendental* one, a *conditio sine qua non* that *predetermines* the field of possible experiences, that is, reality; nature, so the "hypothesis" establishes, is subjected to strict legality.[1]

Nevertheless, there is more, the experimental scientist, who is in charge of testing scientific hypotheses, whose eyes, ears, hands, tongue, and nose have business solely with empirical reality, has his mind firmly set on the idealized construct science substitutes for the living reality. In short, he plays the same game that the theoretical scientist does; he

[1] In case you are not keeping score, we have already considered two transcendental hypotheses in the constitution of empirical reality: 1) it is a domain of *being* existing and completely determined *in itself*, 2) it is a domain subjected to *strict legality*, which can be mathematically expressed (and only thus can be adequately expressed).

too orients himself by "ideal poles"; he too presupposes strict legality. Numerical magnitudes and general formulae are always the main source of interest, theoretical or experimental. Scientific hypotheses, suggested by "experimentally verifiable facts", are already formulae and ideal relations. So, the experimental physicist cannot challenge the idealized world vision of the theoretical physicist and the "hypotheses" at its core. "Hence, the science of nature is subjected to a mutation of sense and a covering of sense that has more than one level. The interplay between experimental and theoretical physics [...] has a horizon of sense that has suffered a mutation." For Husserl, then, the "mathematizing objectivism [...] attributes to the world itself a mathematical rational essence" (Husserl, 1970: §24). "[T]he substitution by which the mathematical world of idealities, which is a substruction [...] is taken as the only real world, that which is truly perceivable, the world of real or possible experiences: in short, our daily lifeworld" (Husserl, 1970: §9).

Husserl deplores that Galileo did not question "the original sense bestowing act, that which, as idealization, acts on a primitive soil of all theoretical and practical life – the soil of the immediately perceived world" that lies at the basis of his method. Yet, Husserl thought, it is the lifeworld that interests us; it is in this world that we live; it is this world that we want to know inductively from experience ("the certainty of being of all simple experience is already an induction"). But in this world "we do not meet geometric idealities, nor geometric space, nor mathematical time with all its forms" (Husserl, 1970: §9).

What, then, is the purpose of science? Husserl has the answer; it is "to correct in an infinite progression, by '*scientific'* anticipations, the *rough* anticipations that are originally the only possible within the effectively (actual or possible) experienced in the lifeworld" (Husserl, 1970: §9). In other words, the point of science is to *anticipate* experience more effectively than it is possible in the lifeworld; its job is to set *ideals* that, although actually unattainable, can direct our efforts into improving experience. In fact, although Husserl does not go into this, the mathematical science of nature anticipates experience *only* by anticipating the *mathematical form* of experience, its *material* content depending either on meaning already attributed to mathematical symbols or, if previously assigned meaning cannot be sustained, new meanings, whose assignment, however, falls short of the competence of science, since it depends on the scientists' sensibility or guessing abilities. In short, under the presupposition that nature obeys laws whose *form* admits mathematical expression, formulae are devised to express "natural laws", which are then used to predetermine the *mathematical form* of future experience. (I will come back to this soon)

The historical accuracy of Husserl's considerations can be put to test by comparing his conclusions to the ones of a science historian expert (Koyré, 1973: 83; the English version is mine):

> The way Galileo conceives a scientific method implies a predominance of reason over mere experience, the substitution of ideal (mathematical) models for empirically known reality, the primacy of theory over facts. It was only thus that the limitations of Aristotelian empiricism could be surmounted and a truly *experimental* method could be elaborated, a method in which the mathematical theory determines the very structure of experimental investigation, or, in Galileo's own words, a method that uses mathematical (geometrical) language to formulate its questions to nature and interpret nature's answers, which, by substituting the rational universe of precision for the imprecise world empirically known, incorporates measurement as the fundamental and most important experimental principle.

Husserl's conclusions concerning the main traits of modern science are all summarized in this quote, namely, the reification of a methodological construct, the mathematical substruction of empirical reality, the downgrading of the lifeworld (the imprecise world of empirical experience, of the morphological, not the geometric) as a source of knowledge, the theoretical, mathematical predetermination of experience. Even though Husserl was not involved with factual history, he certainly hit the nail on the head concerning the factual development of physics.

I now want to consider the problem of the applicability of mathematics in natural science more carefully. This question was raised in *Crisis*, where Husserl offered the key to understanding how this is even possible. But Husserl was also suspicious of the intromission of symbolic mathematics in science. The primacy of the lifeworld and Man's immediate perceptions entailed, for him, that symbolization and the manipulation of symbols can only be allowed in science in the following cases: 1) when symbols have denotations that somehow relate to entities of the lifeworld or else, if symbols are void of any trace of intuitiveness; 2) when (necessarily meaningless) symbolic manipulations are part of a methodological strategy, a practical but essentially unnecessary way of dealing with *definite* contentual theories (i.e. theories that have to do with Man's perceptions and are syntactically complete so as to be capable of settling any question that has a meaning in their domain – Husserl obviously thought that definiteness was an attainable ideal). This way of avoiding the dangers of "technization", however, has two major shortcomings. First, although definite theories can stand as *ideals*, they are not, due to Gödel's theorem, to be expected in general, and, secondly, symbolic mathematics has a much wider range of applicability in science than Husserl allowed it to have. Is there a better way of dealing with this problem? I want to propose one that takes inspiration from Husserl's analyses of the genesis of modern science in order to account for the *possibility* of applying mathematics in science, but that refuses his conservatism as to the range and scope of this application.

The *scientific* inadequacy of Husserl's views on the mathematization of science follows from his belief that mathematical methods should be kept under strict surveillance so as to avoid what he saw as *philosophical* problems. For science, however, from a *methodological* perspective, such methods are the very opposite of a problem. Moving to ever higher levels of mathematical abstraction and indulging in purely symbolic reasoning grant the theorizing scientist access to ever more powerful mathematical tools of *formal* investigation that often yield *empirically testable* consequences (even though most of the assertions of the symbolic theories he sets in action, those that involve empty symbols, do not directly correspond to anything in principle *perceivable* and *a fortiori* testable).

For Husserl, however, algebra and other forms of symbolic reasoning, although often harmless, when symbols stand for "real" entities, can become *problematic* when symbols stand instead for "imaginary" ones ("empty" symbols). According to him, "[t]he powerful elaboration of signs and the modes of algebraic thinking, a decisive moment that has in a certain sense been rich in future consequences but, in another, disturbing for our destiny" (Husserl, 1970: §9). Symbolic reasoning, no matter in which guise or form, involving meaningful or meaningless symbols is, as Husserl recognized, a powerful scientific method, but it has also, he claimed, "disturbing consequences for our destiny." The situation becomes critical, he thought, when symbols do not correspond to possible intuitions, for assertions involving such symbols are meaningless since their content cannot be traced back to the lifeworld and Man's perceptions. The use of *meaningful* symbolic mathematics is not, for Husserl, in itself, a very serious problem, for it can be epistemologically justified but, like light drugs, it can lead to the abuse of heavier ones. In fact, Husserl claimed, it is a short ride from the invention of algebra and its use in science and geometry (Descartes, Fermat) to the creation of purely formal, intuitively empty mathematics and the complete "technization" (and alienation) it led to.

The problem of the *epistemological* justification of the *scientific* use of symbolic mathematics is not raised in *Crisis*, but it had been approached in a different context, involving instead the *mathematical* applicability of this methodology (for example, in Husserl's 1891 *Philosophy of Arithmetic* in connection with the symbolic technology of arithmetic). Husserl, I believe, did not see any reason for dealing with the problem afresh when it surfaced again in connection with the *scientific* applicability of mathematics, for the scientific use of symbolic mathematics is, as he showed in *Crisis*, fundamentally, a *mathematical* one.

Nevertheless, even the use of *meaningful* symbols, those that correspond through a series of idealizations to contents of the lifeworld, despite its justifiability, also counts as symbolization and a form of technization, although a less alienating one. For instance, analytic geometry already implies, or so Husserl thought, a "debilitation" of the sense of geometry, for it is no longer space, but a mathematical "image" of space that commands our interest. Yet, this is not, by far, the only case of symbolization in science. Algebra gave origin to purely formal mathematical theories, which, as Husserl claimed, when considered *in themselves*, are perfectly legitimate *formal ontological* theories, that is, theories of formal manifolds (among which the *definite* manifolds given by "complete systems of axioms" stand out), but when extending (contentual) mathematical theories, and in particular the mathematical theories of nature, can lead to loss of meaning and "alienation": "[T]he original thinking," says Husserl, "which gives sense to this technique and its true results (even if it is the 'formal truth' proper to the *mathesis universalis*) is here [*i.e. in purely formal mathematics JJS*] put out of the circuit." This passage from the "mathematics of real domains to formal mathematics" is correct and necessary, but "can and must be a method understood and utilized with full consciousness." That is, we must be careful that "dangerous shifts of meaning" do not occur, which is to say, that "the original donation of sense of the method, from where it takes its sense as the realization of the knowledge of the world, be always at our disposal."

The question that bothered Husserl can be formulated thus: How can the use of symbolic mathematics in science be *philosophically* justified from the point of view of a philosophy that puts Man's perceptual experiences as the ultimate ground of justification?[1] Let us first consider the use of algebra in physical geometry, the mathematical theory of physical space. Physical geometry is a science based on *geometric* intuition, which is a refinement, or better, an *exactification* of perceptual intuition. According to its *original* sense, the validation of geometric propositions depends on *geometric constructions in space* in which geometric truth is displayed directly to the mind's eye, often via a sequence of constructions based on axiomatically valid elementary constructions and elementary facts (there is here a constant interplay between sense perception and its exactification, geometric intuition). Now, in using algebra in geometry – analytic, as opposed to synthetic geometry – Descartes and Fermat transferred the burden of validation to algebraic, i.e. symbolic manipulations, *no longer intuitive constructions*. Despite the shift of sense introduced by analytic methods in geometry, symbols still correspond to geometric entities (which correspond, as their exactification, to things that either are or can be given in perception); algebraic manipulations can still be "decoded" into geometric constructions (which can, themselves, be "decoded" in terms of practices of the life-world). Technization is still, so to speak, under control; the original sense of geometry can be recovered.

Formal mathematics, where symbols do not correspond to anything intuitable however, or so Husserl thought, more than technization for practical purposes introduces something more disturbing, *alienation*: purely symbolic manipulations that have no ties with experienceable reality. How, then, can they be *justified*?

Based on Husserl's treatment of "imaginaries" in mathematics, as presented in the double lectures delivered in 1901 in Göttingen, we may *guess* what his answer would be: formal mathematics can only be justifiably used in science if it is a consistent extension of *definite*, i.e. logically complete "meaningful" theories whose domains are idealizations of Man's immediate experiences. Unfortunately, this will not do given that such a requirement would cripple scientific methodology (see da Silva, 2013).

Furthermore, there is an even more fundamental problem that Husserl did not address in *Crisis*, but that had already been dealt with in much earlier works: how is it after all possible to obtain knowledge of entities of a type, belonging, for instance, to the geometric or empirical domain, by manipulating symbols (for example, algebraic symbols) referring to entities of a *different* type (numbers, in the case of algebra)? Part of the answer

[1] My point here, in a nutshell, is that Husserl's answer to this question is not a good answer to *another* question, namely: how can the use of symbolic mathematics in science be *scientifically* justified?

is available in his *Philosophy of Arithmetic*, and here it is: If the system of entities we want to know is *formally identical* to the systems of entities our symbols denote, then whatever is true in one is also necessarily true in the other.

Let me explain what Husserl had in mind. Let *A* be our domain of primary interest and *B* an *isomorphic* copy of it. It does not matter what the elements of *B* are, I only suppose that *B* is more easily accessible to direct experience than *A* (whatever type of intuitive experience the direct inspection of *A* and *B* requires, perceptual or any other). Whatever is true in *B*, provided it involves only relations and concepts for which there are isomorphic correspondents in *A*, is also, upon reinterpretation, truth in *A*. Truth is preserved under isomorphism. This is how Descartes' analytic geometry works: points are given numerical representatives in such a way that geometric properties are represented analytically, and geometric constructions are replaced by algebraic manipulations *isomorphically*. *B* may also be a purely formal domain, defined by a formal theory, for which truth only has a formal sense.

The applicability of mathematics in empirical science is also a matter of formal relations between *mathematical* realms, requiring as prerequisite *the mathematization of our perception of empirical reality*. This is how it goes. By retaining from perceptual experience objective *form* instead of subjective *material content*, a "rough" formal structure that is *already* proto-mathematical is obtained that can be idealized into a mathematical structure proper. Thus, an *ideal* mathematical mold is *imposed* upon experience "exactifying" the "rough" structuring we can *extract* from it by abstracting from perceptual experience. From this point on the applicability of mathematics in science is only a particular case of the applicability of mathematics in mathematics itself. If, for example, we can find a domain *B* isomorphic to domain *A* that idealizes experience mathematically, the theory of *B*, provided it is expressed conveniently, i.e., in the language of *A*, is also true in *A*. However, in general, the first level mathematization of experience, our *A*, is still mathematically too poor to have interesting isomorphic copies with well-developed theories and can profit from being mathematically enriched into a domain *B* (we can think of this as *immerging A* into *B* by a convenient monomorphism). If this embedding is short of being a full isomorphism, the language of the theory of *B* may have symbols that are "imaginary" from the perspective of *A*, that is, symbols that have no interpretation in *A*. In this case, for Husserl, or so I claim, the theory of *B* can only be utilized for dealing with *A* if the theory of *A* is a definite, i.e., a syntactically complete, theory.

In short, by abstraction and idealization, we go from the lifeworld into the world of mathematics. If this mathematical substitute corresponds to the lifeworld in such a way that mathematical symbols correspond to contents of the lifeworld isomorphically - similarly to what happens in analytic geometry, in which numbers and numerical variables stand for geometric entities and variables over the geometric domain in such a way so as to preserve the latter's structural form -, technization (i.e. the substitution of the intuitable by the symbolic) can be justified along the same lines algebra is justified vis-à-vis physical geometry. But when mathematical symbols have no representational value in the lifeworld, i.e. when mathematics is purely symbolic, the ties with the lifeworld are severed. Scientific theories with "imaginary" symbols are no longer, strictly speaking, theories of an idealized version of experienceable reality, but of an *imaginary extension* of it, a *symbolic reconstruction* of perceptual reality, in the words of Hermann Weyl. How, then, can they be epistemologically justified in a way that takes experience into account?

Given that Husserl's answer, or what I take for it, is unacceptable, is there a better one? There is one that imposes itself, I think: theories which incorporate "imaginaries" can only be tested as *wholes* (scientific holism) by means of their *meaningful* (i.e. testable) consequences; isolated propositions cannot in general be empirically verified. The theory of *B* is scientifically justified provided that any assertion which can be interpreted in *A*, but whose justification involves in some way the theory of *B*, is verifiably true in *A*. Of course, the effectiveness of the theory of *B* in dealing with *A* can never be definitively justified once and for all, because a consequence may be derived that is false in *A*. This, by the way, is how Weyl solved the epistemological problem posed by purely symbolic manipulations in science (see da Silva, 2014).

As I see it, Husserl may have been aware of this possibility; the problem is that it does *not* offer comfort for the alienation of Man; rather, it embraces it. "Blind" symbolic manipulations *do* alienate Man, his lifeworld, his experiences, and the testimony of his senses. Yet, science cannot do otherwise if it is to remain efficient. Holism, on the other hand, does not turn its back to the lifeworld, as it too gives Man's perceptions a fundamental role in the justification of scientific theories, no matter how symbolically "contaminated" they may be (more globally than locally, though, as Husserl seemed to prefer).

One point in Husserl's analyses of the mathematization of science that I want to stress is the following: mathematics is *not* intrinsic to experienceable reality, but immediate experience may *suggest* possible routes of efficient mathematization of perception. The conflict Husserl detected between pure and applied mathematics seems to indicate this much. Pure mathematics can be known a priori and apodictically whereas "the concrete universal legality of nature," despite also being mathematical, is only accessible a posteriori and inductively; on the one hand, the purely mathematical (deductive) relation between reason and consequence, on the other, (inductive) natural causality. For Husserl, "[A] feeling emerges, little by little, with a sensation of malaise, of the obscurity inherent to the relation between the mathematics of nature and the mathematics of the space-temporal form [...]" (Husserl, 1970: §9). Why, Husserl questioned, does the mathematics of the real not also offer itself in an apodictic intuition, allowing *complete* axiomatization and deduction to take intuition's place as the official truth-providers, just as in pure mathematics, but is always at the mercy of induction from the facts of experience? In other words, why does the mathematics of the real not give itself directly to intuition? The fact that it does not, but that it must again and again be extracted inductively from experience seems to indicate that, for Husserl, mathematics, *to the amount science requires anyway*, is *not* intrinsic to our experience of reality. Quite the opposite, mathematization is *imposed* on experience on the basis of what experience meagerly *suggests* (although what experience suggests is to some extent already mathematical or proto-mathematical in consequence of the ego's intentional action in molding the crude data of perception).[1] Mathematization is only a convenient *a posteriori* structuring of experience that takes notice of the facts of experience but is not *extracted* from experience. Mathematics, *as utilized by science*, is not a given of experience; rather, it comes from the outside as a methodological device.

That experience, nonetheless, already has some mathematical or proto-mathematical structuring is something that comes out clearly in Husserl's account of the constitution of perceptual space (for, remember, experience is already an intentional construct). Perceptual space, although not strictly speaking geometrical, is proto-geometrical; it has some structure on the basis of which, by idealization, a geometric manifold (*physical* space) is constituted. Idealization, after all, is not creation *ex nihilo*; indeed, as a process of exactification it requires something that is not "exact" to begin with; in this case, perceptual space and its *perceivable* structure. But not even *this* structure is only a matter of perception. Perceptual space also betrays a constitution; it is not simply given but a *prod-*

[1] Even the mathematical structure of physical space is not completely given once and for all as the history of physics clearly indicates. We have moved from a Euclidean to a non-Euclidean structuring of space (better, space-time) in the course of the evolution of science.

uct of intentional psycho-physical systems whose task is to "process" raw sensorial impressions. The constitution of perceptual space – a structured system of possible positions of bodies (points) and the relations among them, such as: point *A* is *closer* to point *B* than to point *C*, *A* is *between B* and *C*, etc. – is a joint contribution of the senses and built-in psycho-physical intentional systems. These relations are perceptually accessible and more qualitative than quantitative. For Husserl, however, perceptual space *is real* space.

This can be easily generalized. Our ordinary, pre-scientific experience of empirical reality has also, inevitably, some structure. The experience of the world is not a chaotic mess, but a structured system of perceptions. And, as we know, structures are the subject matter of mathematics. Any structuring is mathematical and structuring relations, such as order, proximity, contiguity, and gradation of different types, among others, are mathematical in nature and so prone to mathematical treatment. Therefore, the structure of experience is an aspect of the experience itself. Science may and does enrich it, idealizing it, "polishing" it, so to speak, introducing new objects and relations in it, but it does not create it *ex nihilo*. Now we have some inkling as to why mathematization works as a *method*: it is a way of extracting information regarding the *structure* of experienceable reality through more refined mathematical methods. Nevertheless, it cannot, *by itself*, if no semantic content is instilled into the symbols, tell us anything about the *material* content of experience (the *whats* instead of the *hows*).

Husserl admitted this much, namely, that experienceable reality is to some extent already mathematical; he only denied that it is mathematical to the extent science presupposes. The lifeworld is not, as I have already noted, mathematics-free and Husserl knew it. What Husserl may have failed to see, since he did not emphasize it, was, first, that the *objectivation* of experience demands that its *material* content be relinquished in favor of its *formal* content, for form can only be objectified through language – indeed, no linguistic rendering of experience, being as it is, out of need, invariant under isomorphisms (true in all isomorphic copies of any domain where they are true), can singularize material content. Secondly, since science is necessarily formal in the sense mentioned above, it can benefit from purely formal-symbolic mathematics devoid of any material content. For Husserl, the project of science requires that the subjective realm of content (colors, sounds, etc.) has correspondents in the objective realm of form (frequency of radiation, longitudinal waves of determinate frequency and amplitude, etc.). But this is not, as Husserl seems to believe, a presupposition of Galilean science only, but of any *objective* science.

By admitting a proto-mathematical structure to experience, Husserl in a way "humanizes" Platonism. Instead of a strictly mathematical reality out of perceptual reach, a proto or quasi-mathematical reality within human reach which can, for methodological purposes, be represented by an idealized, often structurally enriched mathematical pseudo-reality. However – and this is important – the entire process has only to do with the *form* of empirical reality. As long as material contents – *themselves, not their symbolic "representatives"* – are brought into science, mathematical methods of investigation completely lose their relevance (Goethe's theory of colors, to give an example, is refractory to mathematical treatment). If Husserl had seen this he would, I believe, be less concerned with preserving the possibility of recovering perception from its formal aspects alone. Maybe then he would accept that scientific theories, no matter the amount of mathematics that goes into them, are *always* considered in themselves, independently of *external* donation of material meaning to symbols (i.e. by associating content of experience to symbols), purely formal, and that this is why they can be so efficiently extended by purely formal means. There is no other way for the contour conditions imposed by perception to be taken into account, but by submitting theories to test *as wholes* by means of the formal consequences we extract from them and into which we manage to instill some material content.

Roughly speaking, the structure of a domain is the system of relations that the elements of this same domain establish among themselves abstractly considered, i.e., regardless of *what* the elements or the relations among them are. Hence, the structure of any domain is an *abstract* aspect of this domain that can be reified (as an *ideal* object, or Form, to use Platonic jargon) which can be indifferently instantiated in any domain of a family of isomorphic domains (in Platonic language, all isomorphic domains *participate* in the same ideal Form). Although the structure of two different, but isomorphic domains are *equal*, they are not *identical*, for they are aspects of *different* domains. However, both are instances of the *same* ideal structure; we can say that the same identical ideal structure *projects* itself in equal, but non-identical structures of different isomorphic domains.

Mathematics is solely concerned with structures, be they given as abstract aspects of determinate domains of objects (for example, the ω-structure of the domain of natural numbers) or ideal structures characterized by their properties (for example, the ω-structure as given by second-order Dedekind-Peano axioms). Mathematical theories are always structural descriptions, either *in concreto*, as contentual theories such as arithmetic seen as the description of the structure of the domain of natural numbers, or *in abstracto*, as formal theories, like formal second-order arithmetic.

Let us consider an example. Let us postulate a domain (no matter which or even whether there *really* is such a domain; this postulation is a *free* act of imagination) whose elements (no matter what they are) are ordered (by no matter which binary relation) in a discrete linear order in such a way that there is a first element but not a last one, each element has another element – but only one – immediately following it and each element can be reached from the first in a finite number of steps (*just like* the natural numbers ordered by the successor relation). Regardless of the nature of the objects or the relation that orders them, the above description concerns only *how* the objects of the domain are ordered and is a typical example of a structural description *in abstracto*. An ideal structure is thus posited. Yet, in making this structural description, we may also have had a particular, previously existing domain of entities under our eyes (or in the "mind's eye"); for example, natural numbers ordered by successor relation, which would imply that the account, in this case, would be one *in concreto*, describing the abstract structural aspect of a *particular* domain.

Any contentual mathematical theory can, by formal abstraction, be made into a formal theory. If this is a categorical theory (all models are isomorphic), it is no longer a description *in concreto* of the abstract structure of a particular domain but a description *in abstracto* of an ideal structure. Non-categorical theories cannot completely characterize a structure, since they are incomplete characterizations. But mathematics is often more interested in families of similar structures (for example, groups) than in single structures of the same family (for example, the group S_5). A description (theory) is only capable of characterizing a family of similar structures, that of all the domains that correspond to this description (all the models of the theory).

By keeping in mind that mathematics can *only* provide structural descriptions, we can see how it can be of help when we are precisely interested in the purely structural aspect of our experience of the world. Let us consider another example. Through our immediate experience, we may notice that bodies exposed to the sun feel warmer to the touch, some more than others. Our curiosity is stimulated, and we consequently put ourselves in a *scientific* state of mind. We are no longer content in *describing* our experience; we want to *explain* it, to bring out the "hidden rationality" of the phenomenon. Then, though maybe not always consciously, we formulate the "Galilean" hypothesis: there is a hidden legality connecting the period of time bodies are exposed to the sun and the increase of intensity in the feeling of warmth they cause when touched (and, if we are slightly more scientifically sophisticated, that this relation may depend on the *type* of body in question). We have isolated a particular structural aspect of empirical reality we happen to be interested in. To bring it out, so to speak, we resort to the "Galilean" strategy: we objectify the sensation of warmth, *substituting* it by the objective (scientific) notion of temperature, and different "degrees of warmth" actually or only potentially perceivable by numbers (this depends on how temperature relates to, for example, the length of a thin column of mercury). Now, based on the observable correlation between two series of numbers – one series measuring the body's time of exposure to the sun, another the temperature change in this body due to exposure, idealizing and generalizing inductively – we may be able to arrive at a numerical formula, expressing an idealization of the correlation we want to bring to light. Now, all the questions we want to ask about our immediate experience (for example, how much warmer would a piece of iron feel after being exposed to the midday sun during my lunch break?) can be posed about its mathematical substitute (how much would the temperature of a piece of iron rise when exposed to the midday sun for an hour?). Once our formula is available, and the initial conditions checked, the answer is only a matter of arithmetical calculation. The mathematical substruction of experience is, in this particular case, complete.

One aspect of the Galilean hypothesis in particular is worth noting, it is presupposed that the mathematical "translation" is *adequate*, that is, that the mathematical relation really does disclose something that was hidden in the world. In other words, if one presupposes that experienceable reality admits a hidden structure that is mathematically expressed. This, as Husserl emphasizes, is a *hypothesis*, and a very peculiar one. Our experience can neither confirm it nor can it disconfirm it. The hypothesis is out of reach for empirical testing. If the *real* world is, as Husserl wants, the experienceable world, then its *real* structure is the one we can experience. It can be mathematical in a certain sense; for instance, in our example, we can *experience* that short periods of exposure can cause only small changes in the feeling of warmth, i.e. that the continuum of periods of exposure is related to the continuum of increase in the warm feeling in a *continuous* manner.[1] This is a *topological* property of experience, and as such mathematical. Its *metrical*

[1] Perception can also display *quantitative* aspects of experienceable reality (*longer* periods of exposure entail *greater* increase in the sensation of warmth) which, however, remain at the level of the morphological (as opposed to the exact). The formula gives these aspects an exact translation, which, although it does not

translation, embodied in the formula that links temperature changes with periods of exposure (which expresses the intuitive properties of continuous correlations analytically), is an idealization that is not in principle capable of direct experience. The Galilean hypothesis consists in taking it as an *adequate* translation of the topological property, *even though it involves more than what meets or can meet the senses*. The *philosophical* error (which, however, is not a *scientific* error) lies in taking a hypothesis for a *fact*. Some aspects of experience can be mathematical, but not always in the same sense as their mathematical translations are.

correspond to anything *hidden* in the real world, can be translated *back* in terms of elements of the experienceable world. Mathematics provides a *representation*, not a faithful *picture*; this is its methodological value.

References

Bloch, Felix (1976). “Heisenberg and the Early Days of Quantum Mechanics.” In *Physics Today* 29, no. 12: 23-27.

Da Silva, Jairo José (2014). *Husserl and the Principle of Bivalence*. In: Hill, Clarice Ortiz; da Silva, Jairo José, 285-298.

Da Silva, Jairo José (2017). “Husserl and Weyl” In Stefania Centrone (ed.) *Essays on Husserl’s Logic and Philosophy of Mathematics*. The Hague: Springer, pp. 317-52.

Hill, Clarice Ortiz; da Silva, Jairo José (2013). *The Road Not Taken*, *On Husserl’s Philosophy of Logic and Mathematics*. London: College Publications.

Hopkins, Burt. (2011). *The Origins of the Logic of Symbolic Mathematics*. London: Bloomington.

Husserl, Edmund (2003). *Philosophie der Arithmetik*. Halle: Pfeffer, 1891; also published in Husserliana Bd. XII (The Hague 1970); English translation: *Philosophy of Arithmetic, Psychological and Logical Investigations with Supplementary Texts from 1887-1901*. Translated by D. Willard, Dordrecht.

Husserl, Edmund (1970). *Die Krisis der europäischen Wissenschaften und die transzendentale Phänomenologie. Eine Einleitung in die phänomenologische Philosophie*. In Husserliana. Bd. VI ed. W. Biemel, Husserliana (The Hague 1954); English translation: *The Crisis of European Sciences and Transcendental Phenomenology*. Translated by David Carr Evanston. Ill.

Klein, Jacob (1969). *Greek Mathematical Thought and the Origin of Algebra*. Translated by Eva Brann. Cambridge, Mass : The MIT Press.

Koyré, Alexander (1956). “Les origines de la science moderne.” *Diogène* 16: 14-42.