ISSN 2029–2236 (print)
ISSN 2029–2244 (online)
SOCIALINIŲ MOKSLŲ STUDIJOS
SOCIETAL STUDIES
2013, 5(2), p. 481–499.

WHAT CAN THOMISTIC PHILOSOPHY OF NATURE CONTRIBUTE TO PHYSICS?

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Received on 17 October, 2012; accepted on 30 April, 2013

Abstract. *To date it is unknown why mathematics is working in physics. Only the fact that it does work is well known. Physics is thus viewed as consisting of two bodies of knowledge – experience and mathematics which are only interlocked, but not organically united. This article searches for such an organic union. In more detail: experimental physics is ultimately based on elementary particles, which Thomistic philosophy of nature can account for by hylomorphism. Therefore, experimental ehysics and Thomistic philosophy of nature share comparable views of their common object. On the other hand, theoretical physics applies mathematical formulae to natural processes. Thanks to their success in describing such processes, these formulae are called 'laws of nature'. But these laws do not refer to any particular individual material thing the behaviour of which they are supposed to describe, and the reason for their success is unknown. Contemporary theoretical Physics and Thomistic philosophy of nature are far away from each other.*

In order to find the organic union referred above, this paper proposes a basic idea for obtaining physico-mathematical theories from experience. For this purpose, it analyses experiments and particularly measurements as intermediators between the material world and physico-mathematical theories. It turns out that the object of theoretical physics is experienced reality, but only after two severe modifications. The above-mentioned programme starts from the unmodified experience and has as its philosophical core the thomistic version of hylomorphism and the principle 'agere sequitur esse'. It is innovative and can be expected to yield more insight into the relationship between physics and mathematics than the division

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ISSN 2029–2236 (print), ISSN 2029–2244 (online)
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of speculative sciences in metaphysics, mathematics and others proposed by Aquinas in his Expositio super Librum Boethii de Trinitate.

Keywords: *Physics, mathematisation, double cut-off, foundation, hylomorphism, agere-sequitur-esse.*

Introduction

To date physicists do not know *why* mathematics is working in physics. Only *the fact that it does work* is well known. *Working* means that physicists more or less successfully 'apply' mathematical expressions to natural processes, wherefore these expressions are called 'laws of nature'. The application in turn always involves some experimental activity. This is why the knowledge of the fact that mathematics does work in physics is a sort of *practical* knowledge. It seems that experiments cannot be based on or reduced to *thought* experiments. Thence it seems that the knowledge of why mathematics is working in physics cannot be reduced to a purely *theoretical* knowledge.

Additionally, the said application is always hypothetical and thus not necessarily definitive. It does not match with the expectation that for each type of natural processes there should essentially be only *one* physico-mathematical theory. Therefore, in addition to the hypothetico-deductive character of mathematics *per se*, the hypothetical character of the "application" of mathematics to natural processes contributes strongly to the epistemological climate in physics.

The removal of this lack of self-understanding of physics would certainly be beneficial for the depth of physical knowledge. But where should such an amendment of selfunderstanding start from[1]? Perhaps one could learn something from the attempt of solving a similar problem, namely the 'Bohr-Einstein debate'. It began in 1927 between Niels Bohr and Albert Einstein and dealt with the question of the completeness of quantum theory, which then was revolutionary. In 1935, both Einstein (with his coworkers) and Bohr published an article under the same title: "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?"[2]. Einstein and his coworkers answered 'no'; Bohr's answer was 'yes'.

For our purposes it is sufficient to note that the arguments proposed in that debate are partly *mathematical* (clothed into thought experiments). This, however, cannot possibly

1 The present article takes into account only arguments taken from contemporary physics. A brief account of the essential changes from medieval philosophy of nature to physics in the modern sense, during the scientific revolution of the 16th and 17th centuries, is offered in Larenz, R. Does Physics need a second scientific revolution? *International Journal of Sino-Western Studies*, Vol. 4, 2013. Online www.sinowesternstudies.com.

2 Einstein, A.; Podolsky, B.; Rosen, N. Can Quantum-Mechanical Description of Physical Reality Be Considered Complete? *Physical Review*. 1935, 47: 777-780; and Bohr, N. Can Quantum-Mechanical Description of Physical Reality Be Considered Complete? *Physical Review*. 1935, 48: 696-702.

be expected to yield an understanding of the relationship of a physico-mathematical theory to material things, because the problem would have only been shifted but not solved. That is to say *the explanation of the relationship of mathematics to material things must necessarily begin with only one of both sides*. If one takes the stance that material things are, in some sense, *prior* to mathematical expressions referred to them, the relationship of mathematics to material things has to be a *foundation* of those particular mathematical objects and structures based on these very same material things.

This is also the reason why the concept of *interpretation of a theory* should be absolutely avoided. Only a *foundation of a theory* can be admitted. Such a foundation must necessarily depart from ordinary experience, and this is why the Aristotelian philosophy of nature and consequently also the Thomistic one are good tools for attempting to answer the question of why and how does mathematics relate to material things.

It must be admitted, though, that neither the Aristotelian nor the Thomistic philosophy of nature has never been seriously brought into contact with the distinctive elements of modern physical science, namely with experimentation in general and measurement in particular, and with the difference between experiment and theory. Therefore, the explanatory power of these philosophies has never really been tested.

This article tries to do that by proposing the basic idea for a *foundation* of the relationship of certain mathematical objects and structures to nature. It can be hoped, therefore, that a real problem of physics offers a way of updating Thomistic philosophy of nature. In fact, physics might be the science in which the symbiosis between science and philosophy of nature can be established more easily.

The way towards this goal consists of two parts: first, a further specification of the problem already identified (sections II, III and IV). Second, the first steps of the solution to that problem (sections V, VI and VII). They will not be a mere application of traditional Thomistic philosophy of nature, but rather an innovative confrontation of its core principles with experimentation.

1. A Systematic Defect in the de facto Existing Mathematical Physics (i): the tendency towards total mathematisation

In order to show the relevance of the problem mentioned above, we present quotations from four renowned physicists. No commentary is needed, despite different historical contexts and philosophical backgrounds. Likewise it is less important for our purpose that the two first quotations concern theoretical physics in general, meanwhile the other two quotations refer only to quantum theory. All these quotations point clearly towards the same basic problem and have never been seriously contradicted. Therefore, they can be considered to represent the majority of physicists.

First, **Einstein** (1950): physico-mathematical concepts have nothing to do with experience, but the more with the human inventive genius. Theoretical concepts are absolutely arbitrary and free inventions of the human mind[3]. "The very fact that the totality of our sense experiences is such that by means of thinking (…) it can be put in order, this fact is one which leaves us in awe, but which we never shall understand. … The fact that it is comprehensible is a miracle. "[4]

Second, Eugene P. **Wigner** (1960): "The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve. "[5]

Third, Richard P. **Feynman** (1967): "I think, it is safe to say, that no one understands quantum mechanics. Do not keep saying to yourself, if you possibly can avoid it, "But how can it be like that?" because you will go "down the drain" into a blind alley from which nobody has yet escaped. Nobody can know how it can be like that"[6].
Fourth Roger **Penrose** (1986): "I should begin by expressing my general attitude to present day quantum theory, by which I mean standard, non-relativistic quantum mechanics. The theory has, indeed, two powerful bodies of fact in its favour, and only one thing against it. First, in its favour are all the marvellous agreements that the theory has had with every experimental result to date. Second, and to me almost as important, it is a theory of astonishing and profound mathematical beauty. The one thing that can be said against it is that it makes absolutely no sense!"[7]

All these views are radically different from the naïve idea of Galileo Galilei that nature is a book written in mathematical letters[8]. 350 years later, we have the famous passage from the introduction to the "Principles of Mechanics" by Heinrich Hertz (1894). Leaving aside the context of history of science (mechanical determinism, formulation of mechanics without the term 'force', introduction of the concept of 'system'), the relationship between theory and (perceived) material reality is expressed in the following lines, which owe much to Kant's epistemology:

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3 Cf. e.g. Einstein's 'epistemological creed' in his Autobiographical Notes in Schilpp, P. A. (ed.) *Albert Einstein - Philosopher and Scientist*. La Salle (Illinois, USA): Open Court, 1970, p. 5

4 Einstein, A. Physics and Reality. Philadelphia, Pennsylvania, U.S.: *Journal of The Franklin Institute*, 1936, 221,3: p. 349-382, quotation p. 351.

5 Wigner, E. P. The Unreasonable Effectiveness of Mathematics in the Natural Sciences. *Communications in Pure and Applied Mathematics*, New York: John Wiley & Sons, Inc., 1960, vol. 13, No.1, last paragraph. Also accessible on-line, for instance, at www.dartmouth.edu/~matc/MathDrama/reading/Wigner.html. Wigner is a major figure in the development of quantum theory during the 30's, 40's and 50's of the 20th century.

6 Feynman, R.P., *The Character of Physical Law*, Cambridge, MA: MIT Press, 1967, p. 129. Feynman is a major figure in the development of quantum theory during the 40's, 50's and 60's of the 20th century.

7 Penrose, R. *Gravity and State Vector Reduction*, in: R.Penrose and C. J. Isham (eds.), Quantum Concepts in Space and Time; Oxford: Clarendon Press, 1986, p. 129. Penrose is a major figure in the development of mathematical tools in quantum and relativity theory during the 70's and 80's of the 20th century.

8 Galileo uses this metaphor: "La filosofia è scritta in questo grandissimo libro che continuamente ci sta dinanzi agli occhi (io dico l'universo), ma non si può intendere se prima non si impara a intendere la lingua e conoscere i caratteri nei quali è scritto. Egli è scritto in *lingua matematica*, e i caratteri sono trianguli, cerchi ed altre figure geometriche, senza i quali mezzi è impossibile intenderne umanamente parola; senza questi è un aggirarsi vanamente per un oscuro laberinto." Galilei, G., Il Saggiatore. Opere, Edizione Nazionale, Firenze: Barbera, vol. VI, 1929-1936, p.333.

"The most direct, and in a sense the most important, problem which our conscious knowledge of nature should enable us to solve is the anticipation of future events, so that we may arrange our present affairs in accordance with such anticipation. As a basis for the solution of this problem we always make use of our knowledge of events which have already occurred, obtained by chance observation or by prearranged experiment. In endeavouring thus to draw inferences as to the future from the past, we always adopt the following process. We form for ourselves images or symbols of external objects; and the form which we give them is such that the necessary consequents of the images in thought are always the images of the necessary consequents in nature of the things pictured. In order that this requirement may be satisfied, there must be a certain conformity between nature and our thought. Experience teaches us that the requirement can be satisfied, and hence that such a conformity does in fact exist. [...] The images which we here speak of are our conceptions of things. With the things themselves they are in conformity in one important respect, namely, in satisfying the above mentioned requirement. For our purpose it is not necessary that they should be in conformity with the things in any other respect whatever. As a matter of fact, we do not know, nor have we any means of knowing, whether our conceptions of things are in conformity with them in any other than this one fundamental respect.

The images which we may form of things are not determined without ambiguity by the requirement that the consequents of the images must be the images of the consequents. Various images of the same objects are possible, and these images may differ in various respects."[9]

It can fairly been said that modern physics is penetrated by mathematical structures and rationality, and quite successfully so. At the same time, physics is very poor in picturing the richness of reality as perceived by ordinary experience. Abstract concepts dominate, whereas all that belongs to the individuality of things and unrepeatability of events, is left to the activity of the single experimenter. But this activity is not represented by a body of conceptual knowledge *within* physics. Again, this is a way of saying that physicists lack knowledge of the reasons why certain mathematical objects relate to material things in the way they do, and as successfully as they do.

This lack of self-understanding of physics is a serious defect. Yet the success of mathematics in physics is a powerful factor that motivates physicists to *drive* physics *ahead* on the path of mathematisation. Specifically, mathematics is not just a *tool used in physical science*, the content of which is essentially non-mathematical. Rather mathematics is increasingly considered to be the *source of ideas in physics,* as the following text shows:

"Although Mathematics and Physics have grown apart in this century, Physics has continued to stimulate mathematical research. Partially because of this, the influence of Physics on Mathematics is well understood. However, the contributions of Mathematics to Physics are not as well understood. It is a common fallacy to suppose that Mathematics is important for Physics only because it is a useful tool for making computations. Actually, Mathematics plays a more subtle role which in the long run is more important. When a successful mathematical

9 Hertz, H. *The Principles of Mechanics, Presented in a New Form*. London: Macmillan 1899, Introduction. Reprint New York: Dover Publications 1956; 2nd edition 2003.

model is created for a physical phenomenon, that is, a model which can be used for accurate computations and predictions, the mathematical structure of the model itself provides a new way of thinking about the phenomenon. Put slightly differently, when a model is successful it is natural to think of the physical quantities in terms of the mathematical objects which represent them and to interpret similar or secondary phenomena in terms of the same model. Because of this, an investigation of the internal mathematical structure of the model can alter and enlarge our understanding of the physical phenomenon. Of course, the outstanding example of this is Newtonian mechanics which provided such a clear and coherent picture of celestial motions that it was used to interpret practically all physical phenomena. The model itself became central to an understanding of the physical world and it was difficult to give it up in the late nineteenth century, even in the face of contradictory evidence. A more modern example of this influence of Mathematics on Physics is the use of group theory to classify elementary particles."[10]

The next step would be that mathematics becomes the *leading*, even the *exclusive* factor in shaping physics. One way of attempting this is the so-called (quantum) theory of measurement. It is not necessary to go into details in order to get the basic idea: while measurements always have been considered as a *bridge* between nature and mathematics, the idea of *Theory* of measurement transforms the bridge into something *exclusively* mathematical. This spirit has been expressed as follows:

"We shall hope to have established a systematic description of the quantum mechanical measurement process together with a concise formulation of the measurement problem. In our view the generalized mathematical and conceptual framework of quantum mechanics referred to above allows for the first time for a proper formulation of many aspects of the measurement problem *within* this theory, thereby opening up new options for its solution. Thus it has become evident that these questions, which were sometimes considered to belong to the realm of philosophical contemplation, have assumed the status of well-defined and tractable *physical* problems."[11]

This would lead to a total absorption of physics into mathematics. Eventually, only physical names of mathematical objects would remind one of a relationship of mathematical objects with material reality. Nevertheless, the concept of theory of measurement retains the basic idea of measurement as a *confrontation of two material things*, because it tries to *incorporate* measurements into a physico-mathematical theory, not to *eliminate or simply overlook* them. Even though the distinction between mathematics and reality apparently vanishes and thus the predominance of mathematics is at its highest, the *form* of the physico-mathematical theory as a theory of *measurement* acknowledges the theory-shaping power of real measurements. This form is not demanded by mathematical reasons, but rather it must be considered as an experiential reality logically previous to the theory.

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10 Reed, M.; Simon, B. *Methods of Modern Mathematical Physics*, vol. I. New York, San Francisco, London: Academic Press, 1972, p. ix.

11 Busch, P.; Lahti, P.J.; Mittelstaedt, P. *The Quantum Theory of Measurement.* Berlin, Heidelberg, New York: Springer-Verlag, 1996 (2nd edition), p. IX. Italics by authors. As far as I know, this book is the first monograph at all on quantum theory of the measurement process, after decades of journal articles only.

Whatever the particular mathematical features of a theory of measurement might be, the latter departs – in practice - from already *existing* physico-mathematical theories in order to obtain – guided by the idea of 'mathematising the bridge' – supposedly more complete physico-mathematical theories. The existing physico-mathematical theories are thus considered *incomplete*. Theories of measurement, then, cannot *eliminate* that incompleteness, because they continue being dependent on the previous physico-mathematical theories.

String theories can be seen as another sort of mathematisation of physics. They came about for formal mathematical rather than physical reasons. In comparison to all previous physico-mathematical theories, the degree of speculation in string theories is generally considered to be much higher[12]. Thence they are not taken into account in the following.

2. A Systematic Defect in the de Facto Existing Mathematical Physics (ii): mental deformation of experienced reality

After this short account of the relationship between mathematics and material reality from the point of view of *theoretical* physics, it is appropriate to have a certain picture from the point of view of *experimental* physics. Essential for an experiment is the *interaction* of an experimental *object* and an experimental *apparatus* or *device*. An important type of experiments is given by measurements – an interaction between a measuring object and a measuring instrument. Their results are always real numbers together with some dimension in conventional units. The key word for what is done with the observational data produced by an experiment is 'mental deformation'. It is practiced throughout physics, consists of two phases and is referred to in what follows as 'double cut-off'.

The deformation occurs in all experiments, but it is most easily explained by means of measurement. Without loss of generality, we may even restrict ourselves to length measurements, which are familiar to everyone.

The first cut-off consists in cutting measurements off from their global environment by introducing the following tripartition:

(i) no interaction *before* the measurement,

(ii) interaction *during* the measurement, at the end of which the *result* is read off, and

(iii) no interaction *after* the measurement.

Step (iii) of this first phase of the double cut-off makes possible what is called a *result* of measurement. It is hardly possible to experimentally prove the existence of such an end of a measurement process. In fact, how would it be possible to prove experimentally – i.e. by interactions - that there is an interaction free domain? Step

12 There exists, however, some mild criticism concerning the "overmathematisation" of physics, mainly with respect to string theories. See, for instance, Smolin, L. *The Trouble with Physics*. Houghton-Mifflin, 2006.

(iii) seems to be a postulate by which the concept of *result* makes sense, and which is considered justified because of its practical success.

One could ask, whether it is possible at all to avoid such a mental deformation of perceived reality. Would not the dropping of (i)-(iii) cause the end of experimental physics with all its success, because it would be the elimination of *results* of experiments? *Is it not more realistic and reasonable to mentally isolate the measurements as indicated in (i)-(iii) and to be content with successful approximations?*

The second cut-off is even more radical than the first one. It consists in attributing the result read off from the measuring apparatus unilaterally to the measuring object. More precisely, the measured value is attributed only to the object, while the device contributes only to the dimensioned unit.

This attribution is inappropriate, because the different functions 'object' and 'apparatus' have no foundation in nature. (Note that the asymmetry is not eliminated by attributing *both* functions to each side, because their *correlation* would continue.) They are rather brought about by the scientific interest of the experimenter and frequently also by purely practical reasons. The different treatment of object and apparatus in the case of measurement occurs similarly in any other experiment: instead of attributing the result – once produced by the first phase of the double cut-off equally to both sides, it is attributed unilaterally to the object only. Although seemingly harmless and reasonable, the second phase of the double cut-off is an extraordinarily radical mental deformation: it eliminates a symmetry. *The resulting asymmetry cannot be viewed otherwise than as one of the most radical systematic deviations from reality that has ever happened in physics.*

The two phases of the double cut-off form part of a whole: the first phase of the double cut-off (first cut-off) is the end of the measurement-interaction and thus makes possible results at a given moment. The second phase is the unilateral attribution of the result to the object. The experimental device is said to contribute only to the abstract dimensioned unit. Both phases together make possible, or at least are a decisive step towards, the *total* simulation of experiments and in particular measurements *within* a physico-mathematical theory (cf. section II). In other words, the double cut-off opens the door towards a complete mathematisation of physics.

In addition to the mentally operated *deformation* of experienced reality, the elimination of the aforementioned symmetry makes it *impossible* to answer important questions: how is it possible at all to obtain information about one material thing by means of *another* material thing? On what grounds is it possible at all to measure, i.e. to *compare* material things? This basic feature of every measurement could be called *commensurability* and has been lost in the second phase of the double cut-off.

Again, as in the case of the first cut-off one could ask whether it is possible at all to avoid such a mental deformation of perceived reality. Would not the dropping of the second phase make physics with all its success just impossible? *Isn't it more realistic and reasonable to perform a mental deformation of experienced material reality by attaching mathematical objects to individual objects, and so to obtain all sorts of practical advantages in the form of predictions and thus technology?*

In both cases, the answer is the same: It is *neither proven nor even plausible* that mathematics is linked to the material world in the way indicated by contemporary physics. On the other hand, it is also *unknown* which beneficial consequences would follow the double cut-off's dropping. Only one consequence is clear. Renouncing the double cut-off from the outset would require a completely new elaboration of all physical knowledge. One would have to refrain from using the known physico-mathematical theories. Instead, one would have to start *exclusively* from experience.

Here is another corollary: The double cut-off has led to what is known as 'Classical Physics'. Therefore, it is not correct to say that classical theoretical physics corresponds to ordinary experience while quantum theory does not. Classical theoretical physics definitely does not correspond to ordinary experience. Its success is as astounding as is the success of quantum theory.

3. A Systematic Defect in the de facto Existing Mathematical Physics (iii): two concepts related to the double cut-off

In this section we briefly present two concepts as instances of the profound impact of the double cut-off on physics in general. At the same time, they highlight the deep discrepancy of physico-mathematical theories with experienced material reality.

First, the concept of (absolute or relative) precision of a mathematical law of nature. It is often said that a material object follows a given law of nature with more or less precision. *Absolute* precision means that the law and the corresponding measurement(s) match perfectly. *Relative* precision means that theoretical calculation and the corresponding measurement match *more or less*. This way of speaking refers to the comparison of two numerical values, one of which is calculated from the physico-mathematical law of nature, while the other is the result of the measurement(s) attached to the object. But the mere use of the result of a measurement requires the first phase of the double cut-off, so that the concept of *precision of a law of nature* cannot be separated from that first phase.

But once the result is obtained, it is difficult to resist performing the second phase, too. Abstracting from the experimental device entails focusing on the experimental object as if the experiment had never been made. But history cannot be simply forgotten, and that is why experiments are generally considered as a *perturbation of the situation of the experimental object before the experiment*. The three following quotations show how deeply this idea is (still) rooted in the thinking of most physicists. Even though due to their age these formulations have much of a deterministic view of nature, they still sound quite familiar:

> "Truly, our accustomed description of nature and in particular the idea that processes in nature follow strict laws are based upon the assumption that it is possible to observe phenomena *without exercising a notable influence on them*. To attribute a

certain effect to a certain cause makes sense only if we can observe effect and cause without intervening at the same time in the process *perturbing* it."[13]

"By means of the intervention necessary for the experiment we *destroy* certain connections that are characteristic for the microscopic world."[14]

Similarly, Einstein-Podolsky-Rosen formulate: "Any serious consideration of a physical theory must take into account the distinction between the objective reality, which is independent of any theory, and the physical concepts with which the theory operates. ... *Every element of the physical reality must have a counterpart in the physical theory. .... If, without in any way disturbing a system, we can predict with certainty (i.e., with probability equal to unity) the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity.* "[15]

Clearly, the two actions of abstracting from the experimental device and, at the same time, calling its influence on the experimental object a perturbation are at odds. The distinction between 'unperturbed' or 'proper' and 'perturbed' reflects collecting information about the 'unperturbed' object by means of experimental 'perturbations'. In other words, *the first phase of the double cut-off creates a new concept of 'the unperturbed (proper)', although at the price of necessarily co-creating the concept of 'perturbation'.*

Yet, it should not be overlooked that it is only from the perspective of *macroscopic* experience that the 'perturbation' takes place *during* the experimental interaction (which is limited to a 'macroscopic time'). Equally from the perspective of macroscopic experience, the 'proper' is considered to exist only *before* the experimental interaction. Thence, only from the perspective of macroscopic experience, 'real-time' information is excluded. This remark might provide an additional motive to look critically at the double cut-off.

The alternative 'Physics with or without the double cut-off' separates two ways of thinking which cannot be reconciled with each other. It is impossible to pass gradually from one way to the other. Therefore, a real elimination of the double cut-off can only be achieved by not introducing it at all. Not introducing the first phase of the double cut-off makes the distinction between 'unperturbed' and 'perturbed' inexistent. There is no such thing as perturbation. Everything is proper. Then, in the absence of the first phase of the double cut-off, the second phase can no longer take place.

The radicality of this alternative provokes a question similar to those raised in section III: is such a procedure reasonable or even possible *now* after having introduced the double cut-off centuries ago? Undoubtedly, the possibility always exists. As to whether

13 Heisenberg, W. *Physikalische Prinzipien der Quantentheorie* (written 1929/30). Mannheim: Bibliographisches Institut, 1958, IV.3. (Translation and italics are mine.)

14 Heisenberg, W. *Wandlungen in den Grundlagen der Naturwissenschaften*. Stuttgart: S. Hirzel-Verlag, 1959 (9th edition), p. 103. (Translation and italics are mine.)

15 Einstein, A., Podolsky, B., Rosen, N., Can Quantum-Mechanical Description of Physical Reality Be Considered Complete? *Physical Review*. 1935, 47: p. 777-780, quotation p. 777. Italics by the authors.

or not the building up of a new physics *without* double cut-off is esteemed reasonable, depends on how much is held in esteem the unity and thorough intelligibility of physics. And precisely this is lacking, for physics consists of two bodies of knowledge, which are only interlocked, but not really organically united (cf. section II).

An internal reform of physics headed at uniting harmonically both bodies of knowledge faces two requirements: first, it must give an account of why the double cut-off has opened the door for extraordinarily successful physico-mathematical theories. After all, the success of modern mathematical physics as a whole is something real and therefore true. In other words: the internal reform of physics that avoids the double cut-off, must nevertheless show the reason of its success. The second requirement, of course, is the derivation of physico-mathematical theories from experience of the very same material things these theories are referring to.

This makes it clear again that the removal of the double cut-off cannot possibly be headed to *eliminate* mathematics from physics, but to *search for its real location.* In any case, mathematical theories in physics are not something fundamental, but something that needs a foundation. Nevertheless, in this task even the existing physico-mathematical theories might have a role. Even though they are not part of the foundation of mathematics in physics, they most probably are *heuristically* useful.

Precisely the fundamental role of experience in the second requirement for an internal reform of physics makes such a reform, from the very outset, an outsider of current philosophy of physics. For the prevailing opinion is that *every* experience is theory-laden, which in turn is related to the view that experience has little or no cognitive value.

For instance, some programmatic words by Karl Popper might be mentioned: "Even the careful and sober testing of our ideas by experience is in its turn inspired by ideas: experiment is planned action in which every step is guided by theory. We do not stumble upon our experiences, nor do we let them flow over us like a stream. Rather, we have to be active: we have to *'make'* our experiences. It is we who always formulate the questions to be put to nature; it is we who try again and again to put these questions so as to elicit a clear-cut 'yes' or 'no' (for nature does not give an answer unless pressed for it). And in the end, it is again we who give the answer; it is we ourselves who, after severe scrutiny, decide upon the answer to the question we put to nature"[16].

All this shows that an internal reform of physics of the kind sketched in the preceding paragraphs must yield very strong results indeed, if it is to be considered reasonable. The work to be done requires a radical reversal of the present mindset of physicists, that is to say, *first* experience unladen by theories; *then* theories. There are hardly any reasons *a priori* that such an attempt will succeed, except a strong confidence that ordinary experience tells much more than expected.

16 Popper, K.R. *The Logic of Scientific Discovery*. London, Hutchinson & Co., 1959 (1st edition), London: Routledge, 2002, nr. 85. Italics by Popper. This number is the last subchapter of the book and, therefore, serves as an epilogue.

4. The New Rationale (i): basic insights out of experience

The previous sections II-IV have shown that the view of material nature offered by contemporary physics differs deeply from experienced reality, due to the double cut-off. If one wants to renounce the double cut-off and to attempt a new rationale, the question arises: which knowledge of experience is to be the starting point? The pre-modern philosophical tradition has some contents of experience to offer, and additionally the certainty that these contents are not theory-laden. The results of experimental physics match harmoniously with these contents, except for part of the properties of elementary particles, which clearly presuppose a theory (currently the standard model of particle physics). Without pretending to be exhaustive, we mention the following contents:

(i) The plurality and diversity of material things. It is possible to distinguish between direct and indirect observation. There also exists a reasonable distinction between macrocosm, mesocosm and microcosm.

(ii) Every material thing is either a specimen of a species or an agglomeration or aggregation of such specimens. Specimens of species are independent from each other in the sense that the existence of one does not depend on the existence of others. They have a certain 'life time', which sometimes seems to be unlimited. In practice, the belonging of a material thing to a certain species is determined by *specific combinations* of so-called *specific properties* (such as the classical mass and charge, and then spin and others.).
This method of classifying things used in physics can also be found elsewhere. It does not present any reason why precisely these specific properties and not others are grouped together. This remains an important open question.

(iii) Every material thing exerts a *dynamic* influence on others and is influenced by others (activity, passivity).

(i), (ii) and (iii) are contents that have been consolidated for a long time, also in experimental physics. From this the following statements emerge that are part of the Aristotelian-Thomistic tradition:

(iv) The pair of the concepts 'specimen-species' refers to two real aspects of any single material thing: this material thing 'as something individual – as something non-individual'. Both aspects are inseparably united: a non-individualised species never has been observed, as well as never has been observed an individual that has absolutely nothing in common with other individuals. The philosophical evaluation of this complex of experiences is known as *hylomorphism*.

(v) Additionally, every specimen is a structure composed of two kinds of reality: namely as one 'independent reality' with 'dependent realities' or 'properties'. The properties are dependent from an independent reality. The classical names for these two kinds of reality are 'substance' (independent) and 'accidents' (dependent). For instance, the properties called 'energy', 'momentum', 'mass' and 'electrical charge' are dependent realities.

(vi) Also activity and passivity are dependent realities. It is *a material thing* that is active, i.e. exercises an impact on others. Likewise it is *a material thing* that is passive, i.e. receives an impact from others. There is no independent or 'pure' activity or passivity.

(vii) In the practice of experimental physics, the dynamic behaviour of a material thing gives rise to its classification by means of a specific combination of certain specific properies. The words 'give rise' reflect a complex of experiences by which the physicist perceives the link of a certain dynamic behaviour to what the thing is – a specimen of a species. Instead of a link, one could also speak of a sort of *proportionality* of dynamics to what the thing (permanently) is.

The *de facto* existing insight that material things are specimens of a species and that a thing's permanent constitution and its dynamics are not identical, and the subsequent insight in the mediating role of dynamics is used by all physicists without exception. Physics depends vitally on it, even though physicists might have quite different views of what they *de facto* are doing.

Summing up it can be said that the new rationale for obtaining physico-mathematical theories from experience unladen by theories has a solid starting point in ordinary experience enriched by macroscopic experience in contemporary experimental physics. In traditional philosophical terms, one can speak of hylomorphism and of the activity and passivity of hylomorphically constituted material things.

5. The New Rationale (ii): container space versus positional quality

It has been left open, in the preceding section, whether space and time are – so to speak – independent containers of material things or realities dependent on these same material things. In the former case, the hylomorphic structure must be attributed to material things *together with* their containers called space and time. In that case, it is not clear, whether the hylomorphic structure could be attributed to material things alone. But in the case that material things 'carry' or 'generate' their own space and time, hylomorphism obviously refers exclusively to every single material thing. Here is a pertinent classification made by Einstein:

> "[These two] concepts of space may be contrasted as follows: (a) space as positional quality of the material objects; (b) space as container of all material objects. In case (a), space without material object is inconceivable, in case (b), a material object can only be conceived as existing in space; space then appears as a reality which is in a certain sense superior to the material world. The concept of space includes two classes. "[17].

Apparently, this classification has never been seriously explored. One reason for this might be that the alternative 'space as a container' has been rather successful so far. This holds also for the theory of general relativity, which might be interpreted

17 Jammer, M. *Concepts of Space*. Cambridge, Mass.: Harvard University Press, 1993 (3rd edition), p. XV.

in the sense that space is influenced by the things contained in it. Additionally, the container space is one for any number of things contained in it, while space conceived as a positional quality of individual things has as many contributions as there are material things. Obviously, the latter causes the impression to be much more complicated than the former.

However, there are good reasons in favour of the idea that space is a positional quality of material things. The first argument is negative: to date there has never been reported an observation of a container-space. If we assume hypothetically the existence of a container-space that *cannot* be observed, then the question arises of what is the relationship between such a container-space and the 'normal' material things that can be manifestly observed.

The second argument is positive and stems from the exceptionless common observation that different material things are in relation to each other. Accordingly, material things are *not equally everywhere*. In other words, a material thing has a *preferred* position with respect to all other things. As a positional quality is a quality of a material thing, the preferred position of that material thing relative to others can only stem from their *interaction*. The mutual distinction of material things relative to each other harmonises more with a spatial order based on a positional quality of material things than with a container space.

The fact that the interaction of material things is *uninterrupted*, can be inductively derived from the common experience that – first – macroscopic things have a rather unequivocal though variable position in relation to one another. Second, macroscopic things are accumulations of microscopic things. Therefore, accumulations of microscopic things are uninterruptedly in a preferred though variable position to all other accumulations of microscopic things. This indicates – third – that their respective microscopic components have an uninterrupted and possibly variable positional relationship towards one another.

Therefore – fourth – *all microscopic things interact uninterruptedly and pairwise.* This inductive insight is opposed to the first phase of the double cut-off, i.e. the division into domains with interaction and others without interaction. It also severely challenges the concept of inertia and with it the whole conceptual framework of Newtonian physics.

These reasons taken altogether make us adopt the concept of space as a positional quality of material things. Thus, hylomorphism refers to individual microscopic material things *alone*.

6. The New Rationale (iii): the link between specific properties and hylomorphic structure

The criticism of the two cut-off's, the putting in quarantine of all known physico-mathematical theories and the exclusive relying on theory-unladen experience apparently have led us away from the initial problem of the search of an organic union between the two bodies of knowledge. But perhaps it is more appropriate to say that the clear separation of these two bodies is the first step of the problem's solution. But nevertheless, there is much to do. We are still concerned with the beginnings of reflection upon the mentioned experiences (section V, (i)-(vii)). In this section we look at the ways of defining a species used in experimental physics and in the frame of hylomorphism.

The recognition of elementary particles as specimens of certain species is a great achievement of experimental physics, because it presents a sort of foundation or starting point. Specific properties have been crucial in the discovery of every species. As has been sketched in section V, essential for this discovery is the recognition of single specific properties as such and their *specific and invariable combination* as such. In practice, the experimental definition and measurement of single specific properties is performed by using mathematical tools. Nevertheless, for the time being we take it for granted that experience is not only necessary, but decisive for discovering the *combination* of specific properties. But physics does *neither* account for why there are specific properties at all (e.g. spin, mass and charge and other properties (cf. section V(ii))[18] and why they are *invariably combined in certain ways*.

On the other hand, hylomorphism yields a different picture of what a species is. In a nutshell, Aristotelian hylomorphism is a way of saying (i) what a material thing is and (ii) what is its dynamic behaviour: a specimen – a member of a species – is at the same time both 'a representative of a *particular* species' and '*this particular* representative of a particular species'. The specimen inasmuch it is a species is called *substantial form*, and inasmuch it is this and no other particular representative, it is called *prime matter*. At the same time, prime matter is also the element of continuity in changes, where the specimen of one species disappears and other specimen of (possibly other) species appear: the so-called substantial changes.

The terminological shift from 'thing as species' and 'thing as individual' to 'form' and 'matter' stresses the distinction of two groups of aspects: those belonging exclusively to *that particular* specimen of a particular species from those belonging *equally to all* specimens of that particular species. The former group goes back to a principle called *prime matter*, and the latter goes back to a principle called *form*. Every specimen is both substantial form *and* prime matter. Therefore, form and matter are not *things* that are independent from each other. They are often called 'co-principles' of the specimen.

It may be recalled that the hylomorphic approach differs from, though relates to the logical definition of a species. The latter consists in singling out certain individuals of a larger manifold of individuals (genus) by means of a specific difference (*differentia specifica*). Nevertheless, there is certain parallelism between *form* and *differentia specifica*, on the one hand, and *prime matter* and *genus*, on the other. In a colloquial way of speaking, one could say that the more different sorts a *genus* contains, the more

18 Since the general acknowledgement of the standard model of elementary particle physics in the 1970's, the classification of particles is performed in two joint ways: on the one hand quarks, leptons and so-called gauge bosons, which are characterised by the specific properties mass, charge and spin, and on the other hand all other particles which are considered as certain compounds of the former. These compounds also give rise to specific properties. The internationally acknowledged source is the Particle Data Group, http://pdg.lbl.gov/. More information can be easily obtained on the internet by using the following search words 'standard model of particle physics', 'classification of elementary particles' etc.

it ‘approaches’ prime matter. In the same measure the *differentia specifica* takes over more and more determinations and ‘approaches’ the substantial form.

The way of defining a species by a certain bundle of specific properties suggests the question whether hylomorphism is capable of yielding a *rationale* for why there are specific properties at all why they are invariably *combined in certain ways*. In that case, hylomorphism would give insight into the *real structure* of material things, whereas to date physicists have composed specific properties only *mentally* to a bundle. Even though this is not yet an extraction of anything mathematical from experienced reality, the *real infrastructure of the hylomorphic structure* of a particle instead of a *mental combination of specific properties* would be a ‘condition of possibility’ of extracting something from experience.

In this context, the concept of metaphysical degrees might prove capable of being developed. It is used by St. Thomas in the context of understanding the composition of form and matter as a co-implication. One of the many pertinent formulations seems to be particularly suggestive, because it exhibits explicitly the unity of substantial form: “*Quodammodo una et eadem forma, secundum quod constituit materiam in actu inferiores gradus, est media inter materiam et seipsam, secundum quod constituit eam in actu superioris gradus*.”[19]

Let us finally take a look at the thoroughly dynamic character of our material world. The experiments with elementary particles offer abundant evidence that their specific properties are linked to the dynamic processes they undergo. In other words, the classification of particles by their specific properties expresses a link between what a particle is and the way it behaves in dynamic processes. The key role of dynamics suggests looking at the thomistic version of hylomorphism. While the Aristotelian view of hylomorphism is limited to the act-potency structure of form-matter, the thomistic view has hylomorphism as the potency that receives the act of being so that both constitute the real particular specimen of a particular species. This in turn furnishes a connection to the principle ‘agere sequitur esse’. This principle expresses the link between the act of being proper to a particular thing in virtue of its essence, on the one hand, and the dynamics exercised by this same thing, on the other. This in turn means that the essence does not only “measure” the act of being of the thing in question, but also its dynamics.

In the case of a hylomorphically structured thing, the principle ‘agere sequitur esse’ yields thus a ‘hylomorphically structured’ dynamics, i.e. activity and passivity. While activity follows (sequitur) the substantial form, passivity follows the prime matter of the thing in question. And while a thing exercises its activity upon *other* things (without selfinteraction), by its passivity it receives the activity of *other* things. The dynamic outreach of a thing to other things by means of its activity and their passivity (and *vice versa*) can be expected to be a powerful foundation of a *dynamic order*. This can be more suspected than seen by taking into account that the form, by itself, has no

19 Thomas Aquinas, *Quaestiones disputatae de anima*, a.9, c, in: Thomas de Aquino, Opera omnia iussu Leonis XIII P.M. edita. Roma – Paris: Commissio Leonina – Editions Cerf, t. 24/1, 1996.

individual particularities. Therefore, the *mutual interaction* of any two specimens of the same species is *symmetric*. Not in the sense that both actions have equal measures, but rather that both actions are a foundation of *commensurability*. This in turn might be expected to yield what could be called universal laws of nature in a more comprehensive sense. In contrast to the purely mathematical laws of nature known in contemporary theoretical physics, these universal laws of nature in a more comprehensive sense incorporate perfectly the individuality of those things the dynamic behaviour of which they refer to.

In this way, hylomorphism together with 'agere sequitur esse' might be expected to remedy the basic calamity of mathematical physics: material things would not *follow* or *obey* the laws of nature as something extrinsic, like a car 'obediently' follows a road. Rather they *generate* their own laws of nature, notwithstanding the importance of the human researcher in *discovering* and *formulating* those laws of nature. In other words, the laws of nature stem precisely from the things which they refer to, and therefore it is the things that disclose some information about *themselves*. *The principle 'agere sequitur esse' would thus be the basis that dynamics and therefore laws of nature are integrated into the thinking about things. It would be a further question whether and how mathematical laws of nature could be extracted from those more comprehensive laws of nature.*

The work programme sketched in the preceding paragraphs and sections starts from *unmodified* experience and thus avoids deformations of the experienced reality from the very outset. While thomistic hylomorphism alone can be expected to provide insight into the way how the specific properties of a single material thing exhibit themselves as parts of a *unique design*, its combination with the principle 'agere sequitur esse' can be expected to yield insights about a *collective dynamic order*. This is innovative and can be expected to yield more insight into the relationship between physics and mathematics than the division of speculative sciences in metaphysics, mathematics and others proposed by Aquinas in his *Expositio super Librum Boethii de Trinitate*.

7. Final considerations

The discussion presented in this paper focuses on the related views of *experimental* physics and Thomistic philosophy of nature that material things are specimens of species or agglomerations of such specimens. This makes it attractive to search for a deeper connection between both. On the other hand, Thomistic philosophy of nature and present day *theoretical* physics are not so closely related. The reason for this is that theoretical physics is starting from mathematical laws of nature which make it difficult to give an account of an individual, non-exchangeable material thing's behaviour. Its mindset is determined by these laws. In contrast, according to the proposal of this paper, Thomistic natural philosophy starts with these very same individual material things and strives to obtain a sort of metaphysical law of their dynamic behaviour by means of the principle 'agere sequitur esse'. Its mindset is determined by these individuals. If an internal reform of physics by the conceptual means of Thomistic philosophy of nature would really succeed, it would also include a deep change of mindset.

By its application to solving an internal problem in physics, Thomistic philosophy of nature does not set out to solve physical problems. It does not bring in any concepts alien to physics but rather helps to shape concepts within physics. In my opinion, this work programme is worthwhile to be carried out.

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KUO TOMISTINĖ GAMTOS FILOSOFIJA VERTINGA FIZIKAI?

Rudolf Larenz

Santrauka. *Šiandieną nežinome, kodėl fizikoje galime remtis matematika. Gerai žinomas tik tas faktas, kad ja remtis galime. Fiziką sudaro dvi žinių sritys – empirika ir matematika, kurios susijusios, bet nėra organiškai suaugusios. Šiame straipsnyje, pasitelkiant dvi kertines tomistinės gamtos filosofijos koncepcijas – hilomorfizmą ir agere sequitur esse principą, nurodomos priežastyss, kodėl tokių organinių sąsajų verta ieškoti.*

Eksperimentinė fizika iš esmės yra grindžiama elementariųjų dalelių egzistavimo koncepcija. Tomistinė gamtos filosofija savo tyrimus pradeda nuo tų pačių labai individualių materialių elementų bei jų hilomorfinės struktūros, kuri nurodo materialių elementų priklausomybę tam tikroms rūšims arba jų aglomeracijoms. Tad ir eksperimentinė fizika, ir tomistinė gamtos filosofija turi vieną požiūrį į jų tiriamą bendrą objektą.

Kita vertus, teorinė fizika gamtos procesams aiškinti taiko matematinius dėsnius, todėl šie dėsniai pavadinti gamtos dėsniais. Šis taikymas lydimas išbandymų bei klaidų, jis gali būti daugiau ar mažiau sėkmingas, bet visada lieka hipotetiškas. Be to, dėsniai niekada nesiejami su atskiru individualiu materialiu elementu, kurio elgseną jie turėtų apibrėžti.

Siekiant įžvelgti teorinės fizikos ir tomistinės gamtos filosofijos ryšį, šiame straipsnyje aptariami eksperimentai ir specialūs matavimai, tarpininkaujantys tarp materialaus pasaulio ir fizikinių-matematinių teorijų. Aiškėja, kad šis ryšis implikuoja dvi griežtas patirties modifikacijas: siekiant gauti rezultatus, eksperimentai atliekami baigtiniame laiko intervale, o jų rezultatai vienareikšmiškai priskiriami eksperimento objektui.

Norint šių modifikacijų išvengti, vertėtų jų išvis atsisakyti. Šiame straipsnyje siūloma praktinė programa, kaip fizikines-matematines teorijas atskirti nuo patirtinių duomenų. Programos filosofinė esmė kyla iš tomistinės hilomorfizmo sampratos ir iš agere sequitur esse principo. Pirminės (grynos) fizikinių-matematinių teorijų formos atkūrimą siūloma pradėti nuo įvardintų dviejų elementų derinimo pasekmių įvertinimo. Daroma išvada, kad agere sequitur esse principas užtikrina metafizikos ir matematikos atskirtį.

Reikšminiai žodžiai: *fizika, matematizavimas, redukcionizmas, pagrindimas, hilomorfizmas, agere sequitur esse.*

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