Achilles, the Tortoise and Quantum Mechanics

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Abstract

The four antinomies of Zeno of Elea, especially Achilles and the tortoise continue to be provoking issues which are even now not always satisfactory solved. Aristotle himself used this antinomy to develop his understanding of movement: it is a fluent continuum that has to be treated as a whole. The parts, if any, are only potentially present in the whole. And that is exactly what quantum mechanics is claiming: movement is quantized in contrast to classical mechanics. The objective of this study is to show the merits of the Aristotelian approach. It is a good candidate for serving as the philosophical background for understanding fundamental aspects of quantum mechanics. Especially mentioned are the influence of the final state in quantum mechanics that in philosophy could be correlated with the final cause. Like in the work of Aristotle also in this study examples from science are presented to illustrate the philosophical approach. But, in contrast to ancient Greek, the examples now relate to issues which are only fully accessible to the scientifically trained reader. As the main conclusion the dialogue between scientists and philosophers is strongly recommended which will result in progress in both disciplines.

1. Introduction

Without doubt the technological applications of quantum phenomena have an enormous impact on our modern society. One may mention the transistor and diodes which lay on the basis of the information technology and modern solid state lightning. There is extreme good agreement between theoretical quantum mechanical calculations and the experimental findings. The fundamental understanding of Quantum Mechanics (QM) has, however, not yet condensed in a universally accepted framework. Even now, nearly a century after the introduction of QM, scientists speak about the weirdness of QM, see, e.g. [Mullin 2017]. Others evoke the possibility of a large or even infinite number of universes, the so called multiverse approach [Byrne 2008] in order to reconcile the probabilistic character of QM with what they consider the demands of logic.

In the present study an attempt is made to provide a deeper understanding of the fundamentals of QM by proposing a philosophical framework based on ideas of great Greek thinkers link Zeno of Elea and especially Aristotle. For them the understanding or intelligibility of movement or more generally change was central to their philosophical considerations. It is interesting to note that this is also the case in QM, where an unexpected phenomenon was discovered: movement or changes are quantized, i.e. occurring in discrete steps. The quanta, minima of movement, appear to be indivisible, both in theory as well as in experiment. It is perhaps surprising that the analysis of Aristotle regarding movement appears to be a suitable framework to make the findings of QM intelligible, i.e. quitting at least in part its weirdness. In several cases, the arguments presented in the following are not completely new. The author could make repeatedly use of the original work of P.H.J. Hoenen, S.J. (1880-1961). Being available only in Dutch [Hoenen 1947] or Latin [Hoenen 1945], his publications are currently mostly unknown to the scientific community.

The paper is organized as follows. After this introduction the Zeno antinomy on Achilles and the tortoise (AT) is presented. Modern solutions tend to transform the metaphysical aspects to the mathematical level. It is a valid approach but only a truly metaphysical analysis can reveal the fundamental insight hidden in this provoking antinomy. For the further analysis certain philosophical concepts will be introduced like the degree of abstraction and especially the static continuum and, when to addition of the spatial dimensions time is involved, the fluent continuum. Within this framework the solution of Aristotle for Zeno's antinomy is presented. It is shown that this approach sheds new light on the fundamental understanding of QM. Also time itself appears in a new light. Dealing with the fluent continuum one is confronted with the initial and final point of the movement; the latter related in a certain sense with the final cause. The final point of a movement appears in several ways in QM, for example when considering quantum contextuality [Foster 2017] or the role of the observer. At the end some conclusions are given emphasizing the need of an adequate metaphysical basis for the understanding of fundamental issues of modern physics.

2. The Antinomy of Zeno on Achilles and the Tortoise

The paradoxes of Zeno of Elea (490-430 BC) continue to attract attention of philosophers and scientists, see e.g. [Mazur 2007]. The antinomy of AT has reached us by Aristotle. In his Physics, he writes [Aristotle Physics VI]:

> Zeno's arguments about motion, which cause so much disquietude to those who try to solve the problems that they present, are four in number. The first asserts the non-existence of motion on the ground that that which is in locomotion must arrive at the half-way stage before it arrives at the goal. This we have discussed above.
> The second is the so-called 'Achilles', and it amounts to this, that in a race the quickest runner can never overtake the slowest, since the pursuer must first reach the point whence the pursued started, so that the slower must always hold a lead. This argument is the same in principle as that which depends on bisection, though it differs from it in that the spaces with which we successively have to deal are not divided into halves. The result of the argument is that the slower is not overtaken: but it proceeds along the same lines as the bisection-argument (for in both a division of the space in a certain way leads to the result that the goal is not reached, though the 'Achilles' goes further in that it affirms that even the quickest runner in legendary tradition must fail in his pursuit of the slowest), so that the solution must be the same.

Common sense already is sufficient to be convinced that something is wrong with the argumentation. But, of course, one would like to be able to identify the fault in the argumentation. To do so, solutions are offered in mainly two levels of abstraction: the first one, at the mathematical and the second one, at the metaphysical level. Aristotle is arguing on the metaphysical level, and uses the antinomy to develop his ideas about movement (and change in general). By doing so he demonstrates that the antinomy is solved, as the Gedankenexperiment (thought experiment) of Zeno does not correspond with reality. In the next section it will be shown that the analysis of Aristotle opens a route of reasoning that is in accordance with the findings of QM: movement is a fluent continuum that has to be considered as a whole, a quantum.

Coming to the two levels of abstraction (literally process of drawing off), the question arises what is stripped-off and what is what remains. Abstraction supposes a certain manifold of aspects in the being considered. In the Aristotelian hylomorphism one encounters the duals aspects matter and form. Both are principle of being, not being on their own. In the course of abstraction the material aspects are increasingly removed, remaining eventually only the formal aspects. For a discussion of the process of abstraction when obtaining knowledge about an object, see [Driessen 2018]. The first step is reached when all material aspects have been abstracted and only the formal aspects are remaining including the quantitative determinations. Also here increasing levels of abstraction are possible. As an example, a wooden stick can be represented by a cylinder of a certain length and certain diameter and thereafter be considered as a line with a certain length A. By doing so, one now enters the realm of geometry or more general mathematics. Abstracting even the quantitative aspects one ends at the metaphysical level where only the material thing as such is considered.

Searching in literature for a solution for the AT antinomy, one observes that the arguments given mostly belong to the mathematical level. Mathematics has made an immense progress since the time of Aristotle, one of these results is demonstrating that even an infinite sum can yield a finite number. In the case of Achilles and the Tortoise one can consider the paths both run through before reaching the point that the tortoise is overtaken. Assuming one would divide these paths in infinite line parts one can show mathematically that even an infinite number of these parts would add up to a finite values, likewise also the infinite time parts will do so. But we know meanwhile that this mathematical solution does not work for the physical layer. The reason is that both, space as well as time, are quantized according to QM, the minimum being the Planck length and the Planck time respectively [Callender 2004]. These values are extremely small, but asking for a solution of the AT antinomy beyond the mathematical approach.

The most abstract mathematical representation of the distance between the starting point of the race and the point of equal position in space and time is a line with a certain length or duration respectively. It is a continuum which is defined by two points. Philosophically the continuum is a challenging concept, or with the expression of Leibniz, a labyrinth [Leibniz 2002]. The problems arise when one considers the parts of a continuum. In mathematics the part of a line will be of the same mathematical structure, namely also a (reduced) line. Points may lie on a line, but are not parts of a line, see for a discussion of the Aristotelian continuum [Roeper 2006]. The reason is that something without any extension cannot contribute to something with a certain extension. A line, therefore, consists not of a set of points defined by a certain condition, e.g. that these points lie on the x-axis between point A and B. Even an infinite number of points will always remain something with zero extension and not in a line. A (mathematical) continuum can be divided infinitely and between any parts an infinite number of other parts can be placed. That means that the continuum cannot be constructed from the parts. The problem is especially severe if the parts are obtained by employing irrational numbers as, in mathematics, we are not able to add two numbers, one of which is irrational. The reason for this is that in this case a numerical approach is needed with inherently an restricted accuracy.

From the foregoing it appears that the solution of the AT antinomy is less straightforward. The solution of the mathematical level is not in accordance with the fact that there is a minimum in the physical level for the length of the path and its time duration. Also the mathematical level itself needs additional attention as the analysis of the continuum may lead easily to a labyrinth. In the next section we have a more close look on what Aristotle is offering as a solution.

3. Aristotle's view on Zeno's antinomy

The analysis of Aristotle, see [Hoenen 1947] is exceeding the mathematical level and involves metaphysics. The new insight he offers in his analysis is adding a third possibility to a strictly "yes" or "no" in the treatment of reality. He already introduced this third possibility when he discovers a metaphysical structure in every material being, matter and form. This is the so-called hylomorphism. These two principles are not elements of reality, beings, on their own, but are principles of beings, which is evidently more than nothing. Philosophical matter is a potential being that can be actualized by a form. Also the form of material beings is not an element of reality. A being is established when the form is implemented in a suitable matter. For a discussion of hylomorphism and its analogy with hardware (matter) and software (form), see [Driessen 2018].

Going back to the continuum, Aristotle considers the continuum as a whole; only this is element of reality. The parts, evidently cannot be actually present in the whole, otherwise the whole would not be one, but an aggregate of several beings. Of course, the continuum can be, in general, divided in parts. But as long as this division is not carried out the parts are not actually present in the whole, but only potentially. Aristotle explains in [Aristotle Physics VIII]:

> Therefore to the question whether it is possible to pass through an infinite number of units either of time or of distance we must reply that in a sense it is and in a sense it is not. If the units are actual, it is not possible: if they are potential, it is possible.

As had been discussed above in the example of the mathematical line, after division the parts have the same qualitative features, a part of a line is a (smaller) line, of an area a (small) area. Of an iron wire, a short piece of iron wire. What are the boundaries of a continuum? It seems to be something with lower dimension than the continuum in question. For a line these are points, for an area lines, and for a three-dimensional object these are the surface (area). And the qualitative features and boundaries of the parts have the characteristics of the whole, but perhaps with less extension.

The question now arises whether there are natural minima of a continuum? Division to infinity is mathematically possible, but in the physical layer problems arise. The extreme minimum of an iron wire will be the iron atom. Beyond that limit, one obtains something completely new: electrons, protons and neutrons. These are parts with a complete different nature than the of iron, and should not be considered as natural minima of an iron wire. Aristotle and his commentators already discussed the issue of natural minima. Thomas Aquinas [Aquinas 1999] explains with precision the difference of division in the mathematical and the physical level (by the way, physis is the Greek word for what in Latin is called nature):

> Although a body, considered mathematically, is divisible to infinity, the natural body is not divisible to infinity. For in a mathematical body nothing but quantity is considered. And in this there is nothing repugnant to division to infinity. But in a natural body the form also is considered, which form requires a determinate quantity and also other accidents.

A perhaps crude, but illustrative example is the following, see [Driessen 2015]: By dividing a dog one is left with two parts of a cadaver or in best case a mutilated dog and its missing part. That means for higher level of animals like a dog, there is no division possible in parts with the same nature. Each animal is on its own a natural minimum.

3. 1 The fluent continuum

Aristotle now makes a very important step by extending the concept of continuum beyond objects defined with the three space coordinates, the static continuum. For this [Hoenen 1945] employs the Latin expression *continuum permanens*. Aristotle adds the time coordinate and still conserves the general properties of the continuum as described above: the potential parts have the same nature as the whole, division is perhaps possible but as long as this has not been carried out there are actually no parts. This fluent, non-static continuum is called in Latin [Hoenen 1945] *continuum fluens* and movement (kineseis) by Aristotle.

Like before, in the case of the static continuum, one may now ask about the boundaries of the fluent one. For the spatial dimensions it should not be different from the static continuum, points, lines or surfaces depending on the dimensions of the continuum. For time, however, there is only one time dimension. Accordingly the boundaries are two points, the initial and the final time moment. For the potential parts made actual by division in time, one finds similar time boundaries.

Dealing with fluent continua has enormous consequences and allows to provide a final solution to the AT antinomy. For this, Aristotle is now working on the metaphysical level. As shown above, and already stated explicitly by Aquinas, the mathematical level –which is using an *a priori* approach- is not able to solve the antinomy. Only considering an appropriate metaphysics and taking into account the nature (physics) of the continuum in question one adds up with the complete picture.

The movements of Achilles and also of the tortoise are considered as a fluent continuum. What Zeno is proposing in his Gedankenexperiment (thought experiment) is not an truthful picture of reality. Neither Achilles nor the tortoise are running through an infinite number of actual distances; there are no parts in the movement as long as Achilles nor the tortoise is stopping. And what is more important, in reality there is no antinomy. The real world situation is according to common sense, that is, Achilles will pass the tortoise at a given moment. What Zeno has obtained with his approach is nevertheless a positive result. It contributed that Aristotle could arrive at the conclusion that the movement has to be considered as a whole. As will be shown that is exactly what QM is finding in theory and experiment.

What about the natural minimum of the fluent continuum? In analogy with the static continuum where Aristotle and his followers considered a minimum, also here a natural minimum could be expected. And this minimum should be found by inspecting the physical layer of the problem. Already in ancient Greek it had been known that the natural movement of a string in an music instrument is not continuous but related to fix numbers: octave, quint, quart, etc. In ancient Greek, Pythagoras (570-495 BC) and other philosophers were able to develop a complete musical theory based on arithmetic. There is a minimum frequency for a string, the fundamental, and besides this discrete overtones (harmonics). Frequencies lower than the fundamental cannot be reached. Here one could object that a string could be driven by an external oscillator, and then a continuous band of frequencies below the fundamental would be obtainable. But, of course, these wouldn't be natural frequencies of the string in question.

With the introduction of QM the situation regarding natural minima of movements changed. There are minima of movement, with no means to get around. Leibniz stated *Natura non facit saltus* (nature does not make jumps) in order to provide a basis for his work on infinitesimal calculus [Leibniz 1704]. In QM, nature does make jumps, it is not continuous. In [Del Carril 2018] this point is studied with special reference to the work of Pacual Jordan. It is probable that the founding fathers of QM, de Broglie and Schrödinger, had harmonics in mind when developing their theories [Hapern 2014]. This is not so astonishing as mathematically strings in music instruments and particles in QM are described by sinusoidal functions. In QM these are the famous wave functions.

A few examples could be mentioned. Consider an electron, it is characterized by a charge and a magnetic moment due to spinning, i.e. to its rotation around its own axis. The spin is always ½; there are no other values for this specific movement possible neither in theory nor found in experimental research. That means that the natural minimum of the spinning movement is simultaneously also the maximum. Consequently there are no means to reduce or enhance the spinning speed of an electron.

One could also look at double-slit experiments [Wikipedia slit] with photons, electrons or other small particles. If instead of particles, waves would be emitted, an interference pattern would be expected. But interference of particles instead of ballistic transport is somewhat astonishing (For a discussion of ballistic transport of photons or otherwise interference, see [Driessen 2007]). In the light of the foregoing one could make the following analysis: The movement of the particles, emitted by an source (initial point in space and time) and passing through a double-slit and ending at a certain position at the detector screen (final point in space and time) has to be considered as a whole. Any attempt to obtain more information about the precise path of the particle after emission, is dividing the whole. In this case "which-way" information would be obtained for the particle. The consequence is that instead of interference (in QM superposition of several paths) one observes ballistic transport. Is that weird? Why not accept that there are natural minima for movements and that any question about the moving particle between initial and final state has no meaning. Pascual Jordan [Jordan 1972] has commented on these situations where in physics questions can be asked which grammatically con be considered as being correct, but which are meaningless in natural science. He coined his position scientific neopositivism. In this concrete example nature does not provide or contain information about the particle between the initial and final state. Any attempt to achieve information about the trajectory will change the outcome, and this in experiment as well as theory, for a discussion see also [Driessen 2018]. Going back to the static continuum of the iron wire it is not astonishing that by dividing one ends up with something different, namely protons, neutrons and electrons. In a fluent continuum a similar behavior could be expected. By dividing the movement at a double slit set-up in parts, the character of the movement is changed and, instead of interference, ballistic transport is observed.

Another example is superconductivity, a phenomenon only understandable by QM. But now one is considering movement of charges in objects that could extend several kilometers (superconducting cables). That means that one is not any more dealing with micro- or nano-science. It is not the place to explain in detail superconductivity, one may look at [Hyperphysics 2017]. Summarizing the standard Bardeen-Cooper-Schriefer (BCS) theory, one could say the following. In conventional metallic conductors charge is conducted by electrons. In superconductors these are electron-pairs, so-called Cooper-pairs. At low enough temperature, a special QM effect can arise, namely the Bose-Einstein condensation of these Cooper-pairs (for single, not-paired electrons this is not possible). These charge carriers now are all in the ground state. In this state these pairs can move without any resistance, superconductivity has been reached. Why does this happen? The ground state of the Cooper-pairs could be considered the natural minimum of the movement. In the spinning electron we saw that the groundstate, the natural minimum, was the only possible one. In superconductivity there is besides the ground state an excited state where the Cooper-pair is split in two independent electrons. But this excited state is only achieved by supplying a minimum of energy; physicists say that there is an 'energy gap' between these two states. At low enough temperatures there is no way to supply this energy and the Cooper-pairs remain stable. In normal conductors there are scattering of electrons at impurities and other irregularities of the metal, and the movement of electrons are gradually reduced. In superconductors none of these irregularities are able to reduce the movement of the pairs, as these have only a single speed. Only, if enough energy is provided to close the gap, the pairs are broken up and continue with the speed of normal electrons. One could compare it with a car where the cruise control is set to a certain speed, say 100 km/h. Any disturbance by flies, rabbits, birds, small stones, strong wind, gently slopes etc. will not reduce the speed of the car. Only large obstacles, like other cars, a wall, large animals or trees will lead to speed changes or eventually stopping. That is what happens with Cooper-pairs by disturbances below or alternatively in excess of the energy gap.

A special case of the fluent continuum should be mentioned: the time dimension. Aristotle deals with it in his physics [Aristotle Physics IV]. For him, time, like space, is not an object of reality on its own. What is real is position and duration of real objects and events extending in space and time. As stated above the division of a continuum results in parts of the same nature. This holds also for the fluent continuum. As a consequence, points in time are only accessible as start or finish of a movement or change. The point "now" is not part of reality. This issue and others regarding time are discussed by Ursaula Coope; she writes in [Coope 2005] about "the puzzling claim that Aristotle makes: that the now is like a moving thing". Accepting this view, the other antinomy of Zeno, the "frozen" arrow, is easily solved. Time can potentially be divided, but any division results in another movement with a certain duration. On the other hand, adding motionless points one will never end up even with the smallest movement. Physically the difference between a motionless arrow and a "frozen" one obtained by high-speed imaging is the momentum of the arrow. It is an invisible property, but it is effect can be seen when the arrow is hitting a target.

3. 2 The final point of a movement and the final cause
Above we have already discussed that the two borders in the time domain of a fluent continuum are the initial and final point of the movement or change. We also stated that there should be natural minima of the movement. This, of course, is not evident if one restricts oneself to the mathematical level; for the occurrence of natural minima is related to the physical level. The new insight of QM is confirming the metaphysical analysis: there are natural minima, the quanta. If we now consider movement from initial to final point, this movement is a whole, potentially perhaps divisible in parts. But as long as this division has not been made both, the initial as well as the final point characterize the movement. Speaking of a certain finite movement (or more generally change) without referring to the initial and final points is evidently meaningless.

For Aristotle movement is characterized by the four aspects of causality, the famous four causes. In science, causality seems to focus on the initial point. Hawking, for example, states: *Within the universe, you always explained one event as being caused by some earlier event.* [Hawking 1988]. But accepting movement as a whole, the final point contributes to the causality in analogy with the initial point. One of the founding fathers of QM, Arnold Sommerfeld, states explicitly [Sommerfeld 1930]:

> When on occasions I spoke about a new, conditioned causality, it was mathematically founded. It appears namely that we have to calculate emission by a formula, in which the initial and final condition of the atom enters equally and symmetrically. (...) By the way, this is not completely new. Aristotle considered besides the efficient cause also the final cause, as also Leibniz did. It had been in the 18th century that today's form of the concept of causality got through and is now without discussion accepted. It says that the event is exclusive determined by the initial state.

There are many examples where this kind of formula are applied to calculate the probability of movement or change. In photon emission one may mention Fermi's golden rule, where there is complete symmetry with regard to the initial and final state of the atom in question.

An example of spontaneous and stimulated emission of Rare-earth ions may illustrate the impact of this view on experiments and technology. Snoeks et al. studied the light emission of rare-earth ions (Erbium) and did detailed experiments and QM calculations based on Fermi's golden rule [Snoeks 1995]. They changed the final state by changing the optical environment of the Erbium ion in question and could measure the change in decay-rate, which is related to the transition probability. They obtained perfect agreement between experiment and QM theory. If one takes these rare-earth ions between two reflectors, i.e. in a resonator, something unexpected may happen: the emission line gets extremely narrowed and the intensity reaches values only limited by the amount of energy supplied to these Erbium ions. With other words, one is now dealing with a laser. As an example for experiments with lasing of rare-earth ions, see [Yang 2010] with experiments on Neodymium ions. In summary, controlling the final state, one finds in theory and experiment complete different properties of the photon emission properties of the rare-ear5th ion. In QM much emphasis is laid on the observer, who determines the outcome of an QM experiment. One could say the observer is somewhat related to the final cause in that sense that he/she determines the final point of movement (or change). Just by changing the optical properties of the set-up around the ion quite different results are obtained with the example of the rare-earth ions.

In a recent on-line article of the science writer Brendan Foster one finds a well-written introduction to Quantum Contextuality, *a part of the complicated relationship between observers and observations* [Foster 2017]. For our discussion the following quotation is of special interest:

> Quantum mechanics doesn't tell us what electrons are doing when we are not observing those values. The electrons and other particles live secret, unknowable lives, as far as we can predict. A theory that tells us more might give us a complete picture of what electrons are doing at all times. It would also

> tell us the values of things we can measure like momentum or spin, even when we are not trying to measure them.
> Classical Newtonian mechanics is a theory that has these features. Classical particles are like rocks. They have concrete positions and speeds. They have a real story about what they are doing when we don't look at them. Experiments show us the true values of those things.

What is the secret life of electrons and other particles? What would Aristotle say today? Consider a movement from the initial (i) to the final (f) state. This movement is a whole which could potentially be divided in parts. But being in the realm of QM we are mostly dealing with natural minima. That means, there is no division of the movement possible. With strong enough causes, of course, the natural minimum could be broken, but then the qualitative characteristics of the movement have changed. Asking the question about the secret life means that the questioners assumes that there are intermediate states, with other words, that the movement actually is divided parts. Such a division in n sup-movements could be written down as:

initial (i) to final (1)
initial (2) = final (1) to final (2)
initial (3) = final (2) to final (3)
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initial (n) = final (n-1) to final (f)

This kind of division works well for pure mathematics and for Classical Newtonian mechanics, but not in QM. Similar arguments are given above when discussing double slit experiments. It appears that in the light of Aristotle's approach Quantum Contextuality is perhaps less weird than in our current way of thinking which is largely influenced by classical mechanics. Lord Kelvin expresses this classical view as follows [Kelvin 1884]:

> I can never satisfy myself until I can make a mechanical model of a thing. If I can make a mechanical model, I can understand it.

It is a challenging task to find the correct framework that allows a correct interpretation of the results of modern science. It is perhaps an optimistic view, but a reframed background philosophy in the line of Aristotle could probably contribute to a better understanding of modern science.

4. Summary and Conclusions

In the foregoing an ambitious trajectory has been followed. Starting with Greek philosophy and following the approach of Aristotle, a solution to the antinomy of AT is presented. The solution Aristotle offers is that the movement of both, Achilles as well as the tortoise, have to be considered as a whole, a continuum. In this case, this would be a continuum where time is involved, i.e. a fluent continuum, in contrast to a strictly static continuum. The relation of a continuum to its parts needs special attention, and Aristotle proposes a solution which is fundamental to his metaphysics. He introduces a subtlety by introducing a third alternative for the relation to reality for things and movements. Instead limiting the choice to a clear to be (actually) real or otherwise not to be real, he considers also a third possibility, namely potentially being real. For a continuum one could say, that there actually no parts now, but potentially there may be parts after division. In this way he avoids Zeno's antinomy: potentially there may be infinite parts, but Achilles nor the tortoise need actually to run through an infinite number of distances.

Mathematically there are potentially infinite parts in a movement, but when looking for the physics of the problem, one will find only a limited number of potential parts. By further division one encounters eventually a natural minimum. And now QM enters, as in this theory movement is explicitly quantized and natural minima can easily be identified. But making the step from philosophy to the results of modern fields of physics like QM, severe difficulties may arise for the philosophically trained reader. Aristotle used examples from science of his time. For a philosopher like him it was not a great problem to know the state-of-the-art in science of his time. But now the situation has changed as the access to the results of modern science is restricted to the specialist with years of intense study in science. On the other hand, the philosophical background of these scientists exceeds only by exception high-school level.

QM enters and confirms the need of considering movement as a whole. It identifies the natural minimum of movements and is aware that in the calculations the initial and final state enters symmetrically, see, e.g., Fermi's Golden Rule. Mentioning the influence of the final state in the determination of a movement, philosophers immediately remember the famous four causes of Aristotle, especially the final cause. In the literature of the fundamental aspects of QM often appears the "observer". Why is there a need for him/her? Evidently the final state has to be set-up. And dependent of the choice of this set-up certain outcomes are measured, and also calculated: quantum contextuality.

Finally, one should be aware that the present study is only a brief sketch of the validity of an Aristotelian approach to clarify long-lasting issues of fundamental QM. But it is hopefully shown that it is worthwhile to re-think old philosophical concepts and apply them to modern science. For this a dialogue is needed between scientists and philosophers in order to connect the knowledge of both disciplines, the natural sciences (Naturwissenschaften) and humanities (Geisteswissenschaften). It is hoped that this article will stimulate this interdisciplinary dialogue.

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