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The Platonism of Modern Physical Science: Historical Roots and "Rational Reconstruction"

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Abstract
Perhaps the most influential historian of science of the last century, Alexandre Koyré, famously argued that the icon of modern science, Galileo Galilei, was a Platonist who had hardly performed experiments. Koyré has been followed by other historians and philosophers of science. In addition, it is not difficult to find examples of Platonists in contemporary science, in particular in the physical sciences. A famous example is the icon of twenty century physics, Albert Einstein. This paper addresses two questions related to the Platonism of modern physical science. The first is: How is Galileo's Platonism compatible with the fact that he did perform experiments? The solution to this apparent paradox can be found in Plato's late dialogue *Timaeus*. In the dialogue the world has been created by a divine craftsman according to an original plan. The task of the scientist is not primarily to describe the material world, but to reconstruct the original plan. This view has later been known as "God's Eye View". The second question is: If a God's Eye View is unattainable, how is it possible to give a "rational reconstruction" of Galileo's Platonism? The key-word is *idealisation*. It is further argued that idealisation is intimately related to technology. Technology is required to realize ideal experimental conditions, and the results are in its turn implemented in technology. The implication is that the quest for unity in science, based on physics as the basic science, should be replaced by the recognition of the diversity of the sciences.

Keywords Philosophy of science · History of science · Scientific revolution · Experiments · Idealisation · Platonism

1 Introduction

The scientific revolution established physics—in particular mechanics—not only as the most advanced science, but as the ideal model that all sciences were supposed to imitate. This included the social sciences and the humanities as well (Wright, 2004, 4, Cohen, 1994, 101). Various keywords have been used to characterize this development: "methodological

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monism", "unity of science", "scientism", "naturalism", "physicalism" and "scientific fundamentalism".

But what kind of science is physics? An iconic expression of the popular view is the picture of the "father" of modern science, Galileo Galilei, with his telescope. According to this view Galileo liberated himself from the dominating metaphysics of his day—basically Aristotelian philosophy—and constructed a telescope that he directed towards the sky and showed that Jupiter has four moons, and carried out experiments with bronze balls rolling down inclined planes and found the law of freely falling bodies.

Although physics is generally regarded as an empirical science, an empiricist account of physics is too simple. For example, Einstein started out as an empiricist and ended up as a Platonist (Brown, 2011, 153). The role of Platonism in physics was pointed to early. In 1924 the historian of science Edmund A. Burtt published the book *The Metaphysical Foundations of Modern Physical Science* (Burtt 1924/1972).[1] "Modern physical science" primarily includes astronomy, physics (including mechanics) and chemistry, often characterized as the "exact sciences". In a time when the "scientific philosophy" of the logical positivists was on the rise, Burtt argued that modern physical science did not only contain metaphysical elements "by accident", but were built on a metaphysical foundation. The metaphysics of earlier times was replaced by a different metaphysics, based on Plato's philosophy.

Burtt's work was continued by another historian of science, Alexandre Koyré,[2] probably the most influential historian of science of the last century. He argued that Galileo had been the opposite of the prevailing picture of him with the telescope. According to Koyré, Galileo's observations with the telescope were an exception and Galileo had hardly performed experiments at all (Koyré, 1978, 37–38).

James Brown has more recently followed up Koyré's arguments. He quotes Koyré saying that "Good physics is made a priori" (Brown, 2011, 2, Koyré, 1968, 75). Like Koyré he points to the importance of thought experiments, in contrast to real experiments. He offers many examples of thought experiments, both from the history of science and from modern science. Two of his examples are Galileo's thought experiment that refuted Aristotle's law of free fall and Einstein, Podolsky and Rosen's thought experiment that aimed at showing that quantum mechanics (in the Copenhagen interpretation) is incomplete.

An extreme example of Platonism in contemporary physics is what is known as a "Theory of Everything". The point of departure of the theory is the reductionist view that all the sciences may be ordered in a hierarchy that can be represented as an upside down pyramid. At the top we find the human sciences, and at the bottom physics. According to this view one level can be reduced to the next lower level, all the way down to physics, and even to the part of physics that can be called "fundamental physics". Each reduction represents a higher unity (The classical text is (Oppenheim & Putnam, 1958.)). In the end, everything can be reduced to a few fundamental principles. This will be a Theory of Everything (See for example, Hooft, 1994, 20). The endeavor of finding a Theory of Everything is similar to Plato's program for the pursuit of a fundamental principle, the One, in the dialogue *Parmenides* (Plato, 1977, 136A).

[1] Burtt was not the first, though. For a comprehensive overview of the vast literature on Platonism in modern science, see De Caro (2018).

[2] In "Galileo and Plato" he says that Burtt had given "… the best account of the metaphysical substructure (Platonic mathematicism) of modern science." (Koyré 1968, 40n) For a more general account of Burtt's influence, see Villemaire (2002).

The endeavor of finding a Theory of Everything has been heavily criticized. In 2006 the theoretical physicist Lee Smolin published the article "The Crisis in Fundamental Physics" (Smolin, 2006a). He argued that one of the most fundamental principles of science is that we should only regard theories as scientific if we have the possibility to show that they are false by experiments (See also Smolin, 2006b). Although he did not refer to Karl Popper, other critics have referred to Popper and argued that a theory is not scientific if it cannot be falsified (see for example Woit, 2006, 206, Ellis & Silk, 2014).

The first objective of this article is to show that although the uses of thought experiments and the pursuit of a Theory of Everything are no doubt examples of Platonism, there is a third aspect: the idea that the world has been constructed according to an original plan, and that real knowledge includes the reconstruction of this original plan, or model. According to this view, the aim of science is to represent "God's Eye View". It represents a view of scientific objectivity and reality that has been dominating, and made physics the ideal of all sciences. The key source is Plato's late dialogue *Timaeus*.

The second objective is to give a "rational reconstruction" of Platonism.[3] The point of departure is the fact that Galileo *did* perform experiments, and I shall argue that the rational core of his experiments is *idealisation*. Although idealisation has not been a main topic in the history and philosophy of science, a few philosophers of science have tried to give an account of the phenomenon. One of them is the Polish philosopher of science, W. Krajewski, in his book *Correspondence Principle and Growth of Science* (1977). He uses the expression "the method of idealisation", and claims that it is one of the main methods of every advanced science. He especially mentions Galileo, whom he calls the master of idealisation (Krajewski, 1977, 18). Michael R. Matthews has given a detailed description of idealisation in Galileo's treatise of pendulums (Matthews, 2004), and Nancy Cartwright has in several articles and books addressed "Galilean idealisation" (Cartwright, 1983, 1989, 1999, 2022).

Some of these authors refer to Burtt and Koyré, but none refer to Edmund Husserl. However, in his late work *The Crisis of the European Sciences and Transcendental Phenomenology* Husserl gives an account of Galileo and the scientific revolution that is highly relevant. His account was influenced by Koyré, but his interpretation was different. The basic idea was that modern science is grounded in what Husserl called our "lifeworld". It can neither be detached from the lifeworld, nor can it replace it.

I will follow Husserl in arguing that instead of anchoring physical science in a "Platonic Heaven", physical science is grounded in technology. Therefore, physics as an ideal model of science should not be uncritically transferred to other fields of inquiry.

2 Plato's Legacy

Plato's theory of knowledge is constructed on the ideal of mathematics, in particular geometry (Randall, 1970, 239). References to geometry appear in central places when Plato explains what knowledge is, and how it is acquired.

In a famous example in *Meno* Plato shows how it works. The topic of the dialogue is virtue. At the beginning of the dialogue Plato's spokesperson, Socrates, admits that he does not have the faintest idea what virtue is. Meno, on the other hand, allegedly knows what it

[3] In the sense of Lakatos 1970.

is, and comes up with an abundance of examples (Plato, 1956, 71A). Socrates is not satisfied with this answer, because he does not look for examples of virtue, but wants to know what virtue *is*. However, Meno has a counter-argument: How can one look for something when one does not know what it is? The dilemma is that if one already knows what it is, there is no reason to look for it, and if one does not know what it is, one would not be able to recognize it even if one finds it (Plato, 1956, 80B).

Socrates' solution to this dilemma is that in a certain sense one already knows what one is looking for: All learning is *recollection* (anamnesis) (Plato, Meno, 81D). Socrates gives a demonstration of how it works. He sets out to teach Meno's slave boy geometry. First he has been assured that the boy has never learned geometry. Socrates then presents a square of two times two feet and asks the boy to construct a square that is twice that size. The boy constructs a square of four times four feet. Socrates points out that the result is four times the size of the original square. The boy then chooses a side of three feet, but Socrates points out that the result is a square of nine square feet instead of eight. Then Socrates himself draws the diagonal in the original square and constructs a new square with this diagonal as base. The boy acknowledges that the result is a square twice as big as the original square, and Socrates concludes:

> This knowledge will not come from teaching but from questioning. He will recover it for himself (Plato, 1956, 85D).

Therefore, all real knowledge acquisition is recollection. Because the boy was already in possession of the knowledge and had not acquired it in this life, he must have acquired it in a previous life. Therefore, the soul existed prior to the birth of the boy. Plato uses this as a proof of the immortality of the soul (Plato, 1956, 86B).

The core of Plato's theory of knowledge is the theory of Forms (or Ideas). In book ten of the *Republic* he uses the example of a bed to give a short explanation of his theory. He distinguishes between three different sorts of bed: The first is made by God, the second by the carpenter, and the third by the painter. The first is the Form of the bed, it is the real bed, and there is only one. The carpenter makes particular beds, and the painter makes pictures of particular beds. Only knowledge of the Form of the bed is real knowledge, episteme. Knowledge of physical beds and pictures of beds is not real knowledge, but opinion, doxa (Plato, 1955, 597).

The painter's representation of the bed is farthest away from the truth because he only pictures the bed as it *appears*. If we look at a bed sideways, or endways, or from some other angle, it appears different, but the bed is the same (Plato, 1955, 598). Artists use the weakness of our senses to deceive us. The first step is, therefore, to move away from the sensible world, by means of measurements and mathematics. Socrates continues:

> Measuring, counting, and weighing were invented to help us out of these difficulties, and to ensure that we should not be guided by apparent differences of size, quantity and heaviness, and weight—calculations which can only be performed by the element of reason in the mind (Plato, 1955, 602).

But this is only the first step. For example, the geometer uses geometrical figures like triangles and squares, but geometry is not about these material figures. They are just illustrations of the real, ideal geometrical figures. The next step is to turn the attention away from the material world, and direct it "upwards", to the world of ideal objects (Plato, 1955, 510).

It makes sense to say that the ideal bed is the real bed, because it is the model that the carpenter uses to make material beds. It is worth keeping in mind that the ideal bed has normative status as well, because the carpenter tries to make the material bed as close as possible to the ideal bed. However, this does not only apply to artifacts, made by man, but to objects that exist in the world. In particular it applies to celestial bodies. In book seven Plato lets Socrates say the following:

> 'Like this,' I said. 'The stars in the sky, though we rightly regard them as the finest and most perfect of visible things, are far inferior, just because they are visible, to the true realities; that is, to the movements and bodies in movement whose true relative speeds are to be found in terms of pure numbers and perfect figures, and which are perceptible to reason and thought but not visible to the eye.' (Plato, 1955, 529–30)

In the late dialogue *Timaeus* Plato introduces a divine craftsman, the Demiurge, who has constructed the universe according to an original plan. The construction does not take place in time, though. We have reasons to think that the basic idea was that the universe is explained *as if* it had been constructed by a divine craftsman (Randall, 1970, 248). In *Timaeus*, therefore, Plato does not reconstruct the material universe, but the original plan. This explains the above quotation from the *Republic*. The original plan is real, and the material world is an imperfect realization (Cornford, 1977, 34).

Although the world is regarded as an organism, both its macrostructure and microstructure are constructed according to basic symmetry principles. Because the world is the most perfect of all things, it must have the most perfect shape: It must be spherical (Plato, 1971, 33B). The world consists of four elements, which correspond to four of the five "Platonic regular solids": The element fire is made of atoms shaped as tetrahedrons, air is made of octahedrons, water of icosahedrons and earth is made of cubes (Plato, 1971, 56B).

In a more modern terminology we may say that the universe is constructed according to an original theoretical model, and the material world is an imperfect realization of this model. Real knowledge is not about the material world, but about the original theoretical model.

3 Plato and Galileo

In the introduction I referred to the traditional picture of Galileo with his telescope. This view is not without foundation. Galileo made his first astronomical observations in the autumn of 1609 and the winter of 1610, and reported the results in *The Starry Messenger* (Drake, 1990, 134). The most important result was the discovery that Jupiter has four moons. Galileo regarded his observations as strong support for Copernicus' heliocentric system (Galilei, 1957b, 57). This is contrary to the thesis that Galileo was a Platonist. However, if we turn to his main defense of the heliocentric system, in *Dialogue Concerning the Two Chief World Systems*, it is not difficult to find support for the thesis that he was a Platonist.

One example is the "Tower argument": A heavy body is dropped from a tower. If the earth moves, the tower will move with it, and the body will, according to Aristotelean physics, hit the ground a distance from the base of the tower. However, we observe that it falls down to the base of the tower along a vertical straight line. This allegedly proves that the earth is at rest (Galilei, 1970, 126). Aristotle had already used a similar argument to refute the heliocentric hypothesis, and Galileo refers to Aristotle's original argument: If a heavy body is projected perpendicularly upwards and is observed to return along a straight line to the original place, it proves that the earth does not move (Aristotle, 1984, 296b20–25).

But how can we infer that the body will not fall straight down if the earth moves? In the dialogue Galileo shows that this inference makes two fundamental assumptions that belong to the core of Aristotelean physics. The first is that every motion requires a force. Galileo replaces it by the idea of inertial motion. The second is that we observe absolute motion. According to Galileo we observe relative motion (Galilei, 1970, 116). This is later known as the principle of relativity, and defended by Einstein in his special theory of relativity (Einstein, 1905).

The heliocentric hypothesis implies that we in reality move through space with a tremendous speed without observing it. To the Aristotelian, or to the ordinary man, this was unthinkable. Against this Galileo time and again stresses the unreliability of our senses. One of his examples is that when one travels along a street at night one may observe the moon glide along the eaves of the roofs. It looks as if one is being followed by the moon, like a cat running along the tiles. However, reason intervenes and tells us that the apparent motion of the moon is due to our own motion (Galilei, 1970, 256). A few pages later Galileo praises Copernicus because "…with reason as his guide he resolutely continued to affirm what sensible experience seemed to contradict."[4] And another place he says: "But where the senses fail us reason must step in…" (Galilei, 1954, 60).

Later in the dialogue, Galileo explicitly refers to Plato's theory of knowledge as recollection (Galilei, 1970, 191, Koyré, 1978, 207).

According to Koyré Galileo had hardly performed any experiments, and if he had, they played no important part, because Galileo could not have carried out his experiments with the accuracy that he himself claimed. In Koyré's words:

> The 'experiments' which Galileo, and others after him, appealed to, even those which he did actually perform, were not and could never be any more than thought experiments. These are the only kind that could be performed on the objects of his physics (Koyré, 1978, 37).

If we cannot trust our senses, it makes sense to argue that Galileo only performed thought experiments. James Brown uses thought experiments as his main argument in support of Galileo's Platonism, and he particularly mentions Galilei's support for what is often regarded as his main achievement, the law of free fall.

According to Aristotle's law of free fall, heavy bodies fall faster than lighter bodies (Aristotle, 1984, 274a1). Galileo argues that this law implies a contradiction: If we join a heavy and a light body, we may argue that the lighter body will slow down the heavy body. Therefore, the joint body will fall slower than the heavy body. However, we may also argue that the joint body is heavier than the heavy body, and, therefore, falls faster. This contradiction can only be avoided if we assume that the heavy and the light body fall with the same speed.

The problem is, however, that the thought experiment is not valid. Let us take two objects, a stone and a lock of wool. If we drop them, the stone will fall faster than the lock of wool, and if we join them, we do not have one body, but two bodies. The two bodies together would be slightly heavier than the stone, but the lock of wool would nevertheless slow down the stone. For Aristotle friction was a natural part of all motion. The argument

[4] Galilei (1970, 339). Paul Feyerabend in *Against Method* refers to the passages that I have quoted, Feyerabend (1978, 71 and 101). However, although he approves of Galileo's strategy, he portrays him as a Sophist, who denies the important Platonist distinction between persuasion and conviction. (See for instance ibid., 87 and 24–26).

is only valid granted that there is no friction, that is, in vacuum. Brown fails to mention this fundamental assumption, but he is right in pointing to the relationship between Galileo's thought experiments and his Platonism.

Galileo's Platonism goes back to his early writings. In *The Assayer*, published as early as 1623 Galileo compared the universe to a grand book that is written in the language of mathematics, and "its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single word of it" (Galilei, 1957a, 237–8). He explains that when he conceives of any material or corporeal substance, he thinks of it as bounded and having a specific shape, being large or small, being located in a specific place at a specific time, being at rest or in motion, as touching or not touching another body and being one or many. All these properties can be described mathematically, and they are real. What cannot be described mathematically, is not real. This applies to tastes, odors and colors, which.

> ... reside only in the consciousness. Hence if the living creature were removed, all these qualities would be wiped away and annihilated (Galilei, 1957a, 274).

This is close to Plato's world of Forms. However, one difference between Galileo's world and Plato's world of Forms is that Plato's world of Forms is immaterial, whereas Galileo's world is material. One might argue that this is fundamentally un-Platonic. However, the materiality of Galileo's real world is not the materiality of our everyday world, with qualities like color, odors, etc. It has been reduced to ideal material bodies that can be described mathematically. This ideal world is the world of mechanics.

The aim of the theoretical model is to be like the original plan, and that is what Plato carries out in *Timaeus.* We find the same view in the Platonism of contemporary physics. For example, Einstein's basic attitude is reflected in the title of Abraham Pais' biography: *"Subtle is the Lord…"*. The complete quotation is: "Subtle is the Lord, but malicious He is not".[5] (Pais, 1982, printed at the very beginning of the book). In an interview Einstein compared our situation to a child who enters a huge library. The child knows that someone has written the books, but he does not know the languages in which they are written. He suspects that there is a mysterious order, but he does not know what it is (Brian, 1996, 186) (See Brown, 2011, 153).[6]

Another example is Steven Weinberg. In 1976 he gave the talk "The Forces of Nature". The topic of the talk was unification in physics, and at the end of the talk he discussed some philosophical aspects of the project. He said:

> We have all been working in what Husserl called the Galilean style; that is, we have all been making abstract mathematical models of the universe to which at least the physicists give a higher degree of reality than they accord the ordinary world of sensation (Weinberg, 1976, 28).

Stephen Hawking ended his best-selling book *A brief History of Time* with describing the characteristics of such a theory, and concluded that when we have this theory, "…then we would know the mind of God" (Hawking, 1988, 175).[7]

[5] "The original formulation is: "Raffiniert is der Herrgott aber böshaft is er nicht.".

[6] See also (Einstein 1969, 63), (Woit 2006, 2).

[7] Hawking later gave up this project. In Hawking and Mlodinow (2013) they point to the ironical fact that the pursuit of a theory of everything produces a diversity of incompatible theories. In the article they say: "There is no way to remove the observer—us—from our perception of the world." (Hawking and Mlodinow 2013).

It is well known that Einstein never accepted (the Copenhagen interpretation of) quantum mechanics as a complete theory. According to Niels Bohr Einstein's position required a "God's Eye View", which Bohr regarded as unattainable (Favrholdt, 1994, 88). "God's Eye View" would be the perspective of Plato's Demiurgh. It is similar to what Thomas Nagel called "the View from Nowhere" (Nagel 1986).

4 Galileo's Experiments

Both Plato and Galileo emphasized that we cannot trust our senses. But is the only alternative knowledge by recollection, or similar? Plato himself already indicated a third way. I have previously referred to Plato's three beds: The Form of the bed, which is the original model, the material bed, and a picture of a bed. The picture of the bed does not represent knowledge. Artists use the weakness of our senses to deceive us. However, Plato indicates the way out of this situation: Measuring and applying mathematics. The quotation from *Republic* is similar to "Galileo's Maxim": "to measure what is measurable and to render measurable what is not yet so".[8]

We have reasons to believe that Plato had an armillary sphere in bronze in front of him when he wrote *Timaeus* (Cornford, 1977, 74). An armillary sphere is a model of the planetary system. However, because a model is an imitation of a material object, we may argue that in Plato's epistemological system it has the same status as a picture. It represents mere opinion. However, an amillary sphere enables us to learn how a system is constructed and works. Therefore, one might argue that by studying a model of an object one comes closer to the original model. The question if Plato would have agreed with this, is idle speculations, but we shall see that it is a clue to a reinterpretation (or rational reconstruction) of Galileo's Platonism.

I have already mentioned that Koyré was wrong in asserting that Galileo had hardly performed experiments. Koyré's main critic, Stillman Drake, showed that Galileo had in fact performed extensive experiments with balls rolling down inclined planes, and he had arguably obtained the accuracy that he claimed (Drake, 1990, 9ff) Koyré at the end of his life admitted that "… he had overstated the Platonism of the scientific revolution…" and that he "… might have examined more sympathetically the role of experiment there at the dawn of modern science".[9] In 1961 Thomas B. Settle reported that he had reproduced Galileo's inclined plane experiments according to Galileo's own prescription and had obtained results of the same accuracy as Galileo had reported (Settle, 1961).

Galileo primarily carried out his experiments to find a mathematical law of freely falling bodies. An important part of the motivation was to show that Aristotle's law of free fall, where the speed is proportional to the weight, was wrong. However, Galileo knew that the speed of freely falling bodies was much too high to be measured. Instead, he rolled balls down inclined planes.

[8] This quotation is often attributed to Galileo. However, it is far from clear if he ever wrote this (Kleinert 1988). However, it captures a fundamental aspect of his science.

[9] From a conversation with C. Gillispie, quoted in (Stump 2001, 249).

Galileo gives a detailed description of his experimental set up: He used a wooden moulding about 12 cubits long (approximately 5.4 m) and half a cubit wide. In this he made a groove very straight, smooth and polished, and lined it with parchment, which was as smooth and polished as possible. One end of the plane was raised one or two cubits above the other, resulting in an inclination of between 5° and 10°. Down this plane he rolled a bronze ball. The ball was smooth and polished, and made as round as possible.

The ball was rolled several times, and the deviation between two observations never exceeded one tenth of a pulse beat. This is less than one tenth of a second. The experiments were carried out for different weights, distances and inclinations, and in all cases he found that the distance traversed was proportional to the square of the time elapsed (Galilei, 1954, 178–9).

A freely falling body is *natural motion*, but the motion of a bronze ball rolling down an inclined plane can hardly be called natural. However, Galileo had carried out the experiment for different inclinations of the plane, and found that the law is the same in all cases. Therefore he made the "extrapolation" that if the angle of inclination is increased to a right angle, then we have a free fall (Galilei, 1954, 181f).[10] A ball rolling down an inclined plane may, therefore, be regarded as a delayed freely falling body.

It may even be regarded as an analog model of a freely falling body. According to the historian of science Alistair Crombie, models simulating natural structures and motions that could not be handled directly had been used since Greek antiquity, and this development was particularly influenced by *Timaeus*. It originally started with the imitation of the celestial motions by means of armillary spheres and celestial globes, and it later included terrestrial globes, maps and clocks. This kind of models were actively developed in the thirteenth and fourteenth century. The idea of knowledge as construction and explanation as reconstruction became widespread (Crombie, 1994, Vol I, 424 and Vol II, 1090 and 1167).

One fundamental change took part during the scientific revolution: Plato regarded the world as an organism. In the scientific revolution it was replaced by the view that the world is a machine. We see this in particular in Galileo's younger contemporary Descartes. According to Crombie, Descartes' work *The World* (Descartes, 2004) was modeled on *Timaeus*. In Descartes' science and philosophy mechanical models play a fundamental role (Crombie, 1994, Vol II, 1170). For example, he explains the workings of the eye by comparing it to a camera obscura, and the workings of the human body and other organisms are explained as if they were automata (Descartes, 1971, Discourse 5).

Let me return to Galileo's experiments. The experiments at first did not go according to Galileo's plan. He observed that heavy balls rolled faster than lighter balls, but instead of giving up his original hypothesis that speed is independent of the weight of the bodies, he attributed the differences to external factors, in particular friction. Therefore, he tried to minimize friction. In addition, he made the following inference:

> Because if we find as a fact that the variation of speed among bodies of different specific gravities is less and less according as the medium becomes more and more yielding, and if finally in a medium of extreme tenuity, though not a perfect vacuum, we find that, in spite of great diversity of specific gravity, the difference in speed is

[10] He disregarded the fact that a ball rolling down an inclined plane is rotating, whereas a body falling freely is not.

> very small and almost inappreciable, then we are justified in believing it highly probable that in a vacuum all bodies would fall with the same speed (Galilei, 1954, 72).

We might say that Galileo improved his experiment by *idealisation*. But the more he improved them, the more they were removed from the everyday world.

We may distinguish between two different steps in the process of idealisation: The first is "material idealisation", the improvement of the devices that make up the experimental set up of the experiment. The second step is "theoretical idealisation", for example the extrapolation from decreased friction to an ideal case of no friction. Galileo inferred that in vacuum all bodies, for example a lock of wool and a bit of lead, to use his own examples, would fall with the same speed (Galilei, 1954, 72). In other words, Galileo's law of freely falling bodies is only valid for the *ideal free fall*.

Cartwright gives a description of Galileo's experiments that is similar to the one I have given (Cartwright, 1999, 82). Then she adds:

> The problem I am concerned with is not whether we can get the system into ideal circumstances but rather, what makes certain circumstances ideal and others not. [...] But in each case, what makes that arrangement of equipment in those particular circumstances 'ideal' is the fact that these are the circumstances where the feature under study operates, as Galileo taught, without hindrance or impediment, so that its nature is revealed in its behavior.

Cartwright follows Galileo, and argues that the special arrangement that represents the ideal situation reveals the *nature* of the phenomenon. The term "nature" she has taken from Aristotle, and she compares it to an essence "although not so strong" (Cartwright, 1999, 85). This is not different from Galileo's Platonism.

However, Galileo did not only remove complicating factors. He was not only a natural scientist, but an engineer as well, and there are plenty of indications that he was aware of the technical aspects of his investigations of motion. In fact, he did not see a crucial difference between the artificial and the natural. He regarded his own science not only as natural science, but as science of the artificial as well. Indeed, he regarded them as two sides of the same coin. In a letter he discussed various forms of artificial motion, and continued:

> When experience has demonstrated that the motion of heavy bodies falling by nature [free fall, RF] have the same properties as artificial motion, we may confidently assert that the movement of the falling body is the same as we have assumed (Quoted from Drake, 1978, 378).

In the remaining part of this paper I shall argue that we construct simple and idealised models not because they describe essential properties of nature, but because they can be implemented in technology.

5 Science Without God

Galileo's studies of motion were published in 1638 in *Dialogues Concerning Two New Sciences*. In 1725 the Italian scholar Giambattista Vico published *The New Science*. Vico's basic idea was that God has made nature, and only he can really understand it. For Vico it was a paradox that philosophers had almost exclusively concentrated on the study of nature, that only God can know (Vico, 1988, 96). However, man has made society, and can therefore understand what he has himself created. The study of civil society requires a new and different science.

If we acknowledge that Vico was right about natural science, then knowledge of the original plan is unattainable. Immanuel Kant was the first to both acknowledge the Platonism of modern science (in contrast to the empiricists who did not recognize it) and to account for it in a rational way. His approach was the "Copernican turn" in philosophy. He argued that Copernicus discovered that he did not succeed in explaining celestial motions when he assumed that all the stars rotate around the observer, but he succeeded when he assumed that the observer rotates and leaves the stars at rest (Kant, 1956, B XVI).

In the same way, mathematics and classical mechanics are possible because they are a result of *our* contribution to the observations. The certainty of mathematics (arithmetic and geometry) and natural science (mechanics) is, therefore, due to the fact that they are our own contributions to the observed phenomena. In particular, we perceive phenomena in space and time. They represent the form of our empirical intuitions ("Anschauungsformen", Kant, 1956, B 33–34). But Kant made the same error as Galileo and Descartes: He replaced our lifeworld by the "world of physics". But neither perceived space nor our lifeworld is Euclidean (See for example Heelan, 1988. See also Fjelland, 1991).

The alternative to Platonism that I will outline in the following is inspired by Husserl's late work *Crisis*. However, to avoid a common misunderstanding I will first say a few words about Husserl's project in *Crisis*.

What is the crisis of the European sciences? Husserl has no quarrels with the established natural sciences. He says about physics:

> Physics, whether represented by a Newton or a Planck or an Einstein, or whomever else in the future, was always and remains exact science (Husserl, 1970, 4).

With a possible exception of psychology, the same applies to the other sciences. The crisis is rather "… the positivistic reduction of the idea of science to mere factual science." Therefore, science has lost its meaning for life: "In our vital need—so we are told—this science has nothing to say to us." (Husserl, 1970, 6) Some critics, among them Jürgen Habermas, have argued that Husserl uncritically adopts "… an idea of knowledge which preserves the Platonic link between pure theory and practical life." (Habermas, 1966, 286) However, this is at best a controversial interpretation. Husserl does not criticize Galileo for not offering a link between, say, science and ethics. However, for my project this is not important. I will restrict myself to the following, more modest interpretation.

According to Husserl the key to understanding modern science is the philosophy and science of Galileo. Koyré had once been a student of Husserl. Later in life they resumed contact, and Husserl's account of Galileo in *Crisis* was influenced by Koyré. According to Husserl, Galileo was "… at once a discoverer and a concealing genius." (Husserl, 1970, 52) On the one hand he established the ideal of mathematical science, but on the other hand he substituted the "mathematically substructed world of idealities" for our lifeworld. This substitution was passed on to Galileo's successors, "the physicists of all the succeeding centuries." (Husserl, 1970, 49) The consequence was a fundamental *misunderstanding* of modern science. This misunderstanding was the root of "objectivism", "physicalism" and "naturalism".

Husserl's basic idea is that modern science, even the most abstract, is grounded in our "lifeworld". It can neither be detached from the lifeworld, nor can it replace it. He mentions Einstein's theory of relativity, and argues that it is dependent on "Michelson's experiments and the corroborations of them by other researchers" (Husserl, 1970, 125). To perform this kind of experiments, the scientists must be able to move around, to construct and handle instruments, to read scales, and to communicate with other scientists. In other words:

> The visible measuring scales, scale-markings, etc., are used as actually existing things, not as illusions; thus that which actually exists in the life-world, as something valid, as a premise (Husserl, 1970, 126).[11]

I will follow Husserl in arguing that instead of anchoring physical science in a "Platonic Heaven", physics must be grounded not only in our lifeworld, but more specifically in technology. This may be called a "bottom-up" approach, by means of idealisation: Mathematical entities, mechanics, and the rest of physics, is based on technology, and is obtained by idealisation. Physical science is, therefore, intimately related to technology.

I said above that the key word is idealisation. To see how it works, let us return to Galileo's inclined plane experiments.

Galileo relates that he rolled the bronze ball down a groove that was made "very straight", and the ball was made "as round as possible". We understand that the basic Euclidean forms straight line, plane surface, circle and sphere are imperative to the experiment. Galileo was aware of the close relationship between Euclidean geometry and technology. For example, he points out that circle and sphere are the simplest geometrical figures, and he justifies this by pointing out that they are the easiest to produce. A sphere is produced by first making a circular hole in a metal plate, and then a "very roughly rounded solid is rotated at random within it". It will be reduced to a perfectly shaped spherical figure as long as it is larger than the hole. Galileo contrasts the spherical shape to the shape of a horse or a grasshopper, because only "a few sculptors in the world" are able to make such shapes (Galilei, 1970, 209).

As mentioned previously, Galileo himself emphasized that his law of free fall is only valid under ideal conditions, and that it is important to be aware of these limitations. However, he then adds that "the material and shape of the projectile may be chosen, as dense and round as possible, so that it will encounter the least resistance in the medium (Galileo 1954: 251). Therefore, technology realizes the ideal conditions of the experiment.

If we disregard Galileo's metaphysics, we may argue that we construct simple and idealised models not because they describe essential properties of nature, but because they can be implemented in technology. And it is important to keep in mind that this applies to physical science in general, although it is normally not a part of the curriculum. One exception is a much used textbook in physics, Young & Freedman: *University Physics*. I think a lengthy quotation is in place:

> The concept of idealised models is extremely important in all physical science and technology. When we apply physical principles to complex systems, we always use idealised models, and we have to be aware of the assumptions we are making. In fact, the principles of physics themselves are stated in terms of idealised models; we speak about point masses, rigid bodies, ideal insulators, and so on. Idealised models play a crucial role throughout this book. Watch for them in discussions of physical theories and their applications to specific problems (Young & Freedman, 2004, 5).

[11] In *Husserl's Missing Technologies* the philosopher of technology Don Ihde accuses Husserl of neglecting technology (Ihde 2016, 52). This allegation is contradicted by the quotation above. However, Ihde is right in asserting that Husserl never mentions Galileo's telescope (Ihde 2016, 50). There is no reason to deny the importance of telescopic observations. But, if one tries to understand how measurements and mathematics became so dominating in the moderne scientific ideal, the telescope will not be the main focus.

Hacking has made a similar remark. He pointed out that what works in the laboratory, often does not work well in the unmodified world (Hacking, 1992, 59). The reason is that the world is in general not simple, but complex. I will return to this topic in the conclusion.

6 The Origin of Geometry

I have pointed out that to Husserl it was imperative to acknowledge that the natural sciences are grounded in our lifeworld and at the same time account for the Platonist aspects of physical science. The key is Euclidean geometry. If we can give a "bottom up" account of Euclidean geometry, we have solved the problem. Husserl understood this, and this is the topic of his article "The Origin of Geometry", included as appendix VI in *Crisis*.

Let me first return to "Meno's paradox" that I introduced at the beginning: The paradox is that if one already knows what one is looking for, there is no reason to look for it, and if one does not know what one is looking for, one would not be able to recognize it if one finds it. Plato's solution to the paradox was pre-existence of the soul and knowledge as recollection. In *The Tacit Dimension* Michael Polanyi refers to the paradox, and argues that no one will accept Plato's solution. Polanyi's own solution of the paradox is to introduce a different kind of knowledge, that he calls *tacit knowledge* (Polanyi, 2009, 22ff).

The distinction between articulate and tacit knowledge solves "Meno's paradox" and is an alternative to Plato's theory. In the case of Plato, the knowledge is already in the soul because the boy had lived before he was born. In Polanyi's interpretation the boy has lived a "practical life" before he started a "theoretical life". In both cases the task of the teacher is to bring forth what is already potentially present.

Meno emphasized that the boy had never learned geometry, but he is obviously able to recognize a straight line, a right angle and a square, and he is also able to count and multiply small numbers when he constructs a square that is supposed to be twice as large as the original square. But if he had never been instructed in geometry, how had he acquired the basic concepts of geometry? If we follow Polanyi, we might argue that he had acquired it through practical activities in the everyday world. Polanyi formulated this insight as "…*we can know more than we can tell*" (Polanyi, 2009, 4, italics in original). The boy would then be able to recognize, for example, a straight line, but he would hardly be able to give a definition.

Plato would have relegated tacit knowledge to the bottom of his epistemological hierarchy. Polanyi, on the contrary, maintained that skills are a precondition for articulate knowledge in general, and scientific knowledge in particular. For example, to perform experiments requires a high degree of skills. These skills cannot just be learned from textbooks. They are acquired by instruction from someone who knows the trade.

The example of Meno's slave boy is fiction, but it raises the important question about the origin of geometry and geometrical concepts that Husserl addresses in "The Origin of Geometry".

According to Husserl the development of geometry may be reconstructed as follows: The world consists of material bodies, with different shapes and qualities (color, warmth, weight, hardness etc.). For technical purposes some particular shapes are preferred, for example plain surfaces and spherical shapes. The first step is selecting shapes according to their closeness to these shapes. Then they are perfected by cutting, grinding, molding, polishing etc. We may call this process idealisation, and like Galileo's plane experiments we may distinguish between two different steps. The first is material idealisation, like Galileo's construction of instruments. The next step is theoretical idealisation. The ideal geometrical shapes like straight line, plane surface and sphere are limit-shapes ("Limesgestalten"). They are characterized by their symmetry properties. For example, a plane surface has translational and reflectional symmetry.[12] Therefore, all plane surfaces fit.[13]

Even Plato may have agreed to this description of the origin of geometry. But, as we have seen, to represent episteme, geometry must cut loose from its origin. For Plato, the mathematical entities are not limit shapes, but really existing entities. To Husserl, on the contrary, they are idealisations, and therefore, they cannot be detached from our lifeworld. For Plato and the Platonist they are *discovered*. For Husserl they are *invented*. However, when these limit shapes are made the objects of investigation, geometry has become a theoretical discipline.

Although Husserl claimed that the intimate relationship between pre-theoretical, technical practice, and geometry had not been investigated before, he was not the first. It had already been done in more detail by the mathematician William Kingdon Clifford (Clifford, 1955) and the philosopher Hugo Dingler (Dingler, 1911).

7 Conclusion: From Unity to Diversity

Cartwright's point of departure is that our contemporary view of science is dominated by categories favored by British empiricists, in particular Locke, Berkeley, Hume, Ayer and Ryle (Cartwright, 1999, 78). She shows convincingly that their account of science, in particular physical science, is inadequate. I agree that the empiricist view has been widespread, but my starting point has been that Platonism has played a major part in the development of science, in particular physical science (cf. De Caro 2018).

I have emphasized one aspect of Platonism, the assumption that the world has been constructed according to a fundamental plan, or at least that it may be regarded *as if* it has been constructed according to an original plan. Therefore, there is a "God's Eye View" that science should try to adopt. We may also characterize this as scientific fundamentalism. It promotes physics as the ideal science, reductionism and a preference for simplified and idealised mathematical models. We may say that Plato started the "unity of science movement", based on (Euclidean) geometry as the model of all knowledge. A distinguishing mark of geometry is that all possible constructions can be reduced to a few fundamental principles. In the same way it is assumed that the original plan of the world is generated from a few fundamental principles.

We have to acknowledge that this approach has limitations. In general, we can easily model technological systems. In addition we may construct simplified and idealised models that capture important aspects of systems, from various perspectives and for various purposes (Auyang, 1998). But nature is complex, and we cannot in general construct mathematical models that adequately describe the world (Chu, 2011; Landgrebe & Smith, 2023, 188). Therefore, instead of pursuing a scientific ideal based on the unity of science, we should acknowledge the diversity of science (See for example Galison & Stump, 1996).

It is worth keeping in mind that there has been alternatives to the unity of science from the very beginning. An alternative to Plato's theory of knowledge was already offered by

[12] "The plane surface may be defined as one which is of the same shape all over and on both sides." (Clifford 1955, 61).

[13] "Thus plane surfaces are defined by the transitiveness of the relation of fitting." (Campbell 1928, 273).

his pupil Aristotle. Aristotle criticized Plato for maintaining that the objects of mathematics exist apart from material bodies: “And it is evident that the objects of mathematics do not exist apart.” (Aristotle, 1984, 1090a29).

A little simplified we may say that in contrast to Plato’s philosophy, which was inspired by geometry, Aristotle’s philosophy was inspired by biology (cf. Randall, 1962, 30, 220). In fact, Aristotle may be regarded as the founder of biology as a discipline. His philosophy—in particular his philosophy of nature—is fundamentally organic. A distinguishing mark of organic thinking is the importance of the pair of concepts whole/part. Aristotle knew that to study an object, we sometimes have to take it apart. However, we have to be aware of the fact that something is lost. This view is often expressed by the slogan that the whole is more than the sum of the parts.

Although the organic view of nature during the scientific revolution was replaced by a mechanistic conception of nature, Aristotelean biology never completely disappeared. For example, the poet and scientist Johann Wolfgang von Goethe (Goethe, 1988), and the naturalist Alexander von Humboldt belong to this tradition. Goethe is the founder of the field of morphology, and Humboldt is the founder of ecology.[14]

Although Aristotle’s biology is basically qualitative, Aristotelean biology does not necessarily exclude mathematics. This was demonstrated by the polymath[15] D’Arcy Wentworth Thompson in the book *On Growth and Form* (Thompson, 1992). Galileo’s uses of mathematics was based on *measurements*, but if we focus on biological *form*, then the situation is different. Thompson’s approach was followed up by the mathematician Hermann Weyl in the book *Symmetry*, where the fundamental concept of symmetry is pursued in biology and art (Weyl, 1952).

This tradition may be characterized by a quotation from Thompson:

> For the life of the body is more than the *sum* of the properties of the cells of which it is composed: as Goethe said, ’Das Lebendige ist zwar in Elemente zerlegt, aber man kann es aus diesen nicht wieder zusammenstellen und beleben.’ (Thompson, 1992, 41)

This line can be extended to the paleontologist Stephen Jay Gould and to theories of complexity.[16]

Finally, I will mention a third tradition: the humanistic tradition. The central topic of the present article is the scientific revolution during the Renaissance in the seventeenth century. However, the Renaissance started earlier, with the Renaissance humanism of the fifteenth century, with names like Desiderius Erasmus and Michel de Montaigne. As the term “humanism” indicates, it was based on a human perspective, characterized by an awareness of the limits of one’s own perspective, the acceptance of uncertainty and the imperfection of man, and, therefore, a tolerance towards other opinions. Traditionally, the scientific revolution has been regarded as a continuation of Renaissance humanism. I think the philosopher of science Stephen Toulmin was right when he argued that the scientific revolution

[14] Although Ernst Haeckel coined the term (cf. Wulf 2015, 307).

[15] In his foreword to the abridged edition of Thompson’s *On Growth and Form* Stephen Jay Gould says that "according to a legend that could have been true", Thompson was offered professorships in three different disciplines: classics, mathematics and zoology (Thompson 1992, ix).

[16] The best documentation of this tradition can be found in Gould’s magnum opus *The Structure of Evolutionary Theory* (Gould, 2002).

was rather a counter-Renaissance. The human perspective was replaced by the ideal of an absolute perspective based on Euclidean geometry as ideal (Toulmin, 1990, 69ff).

Erasmus and Montaigne lived before the scientific revolution. I have already mentioned Vico, who lived after the scientific revolution. I also want to mention Wilhelm Dillthey. His project in his main work *Der Aufbau der geschichtlichen Welt in den Geisteswissenschaften* is similar to Vico's new science (Dilthey, 1970, 89). Dilthey introduced the distinction between "explanation" ("Erklären") and "understanding" ("Verstehen") for the first time. "Explanation" denotes the tradition from Plato and Galileo, and "Understanding" denotes the "humanistic" tradition. We can understand human language and things created by man, but we can only give causal explanations of phenomena in nature (Dilthey, 1970, 255). Dilthey uses the expression "die Geisteswissenschaften", and it is often translated as "the moral sciences". It is sometimes referred to as "the hermeneutic tradition".

I have described three different traditions in the history of science: The Platonic tradition, the Aristotelean tradition and the humanistic tradition. In *Explanation and Understanding* Georg Henrik von Wright distinguishes between only two main traditions, that he calls the Aristotelean and the Galilean tradition (Wright 2004, 2). However, what he calls the Aristotelean tradition is rather what I have called the humanistic tradition.

One might also increase the number of traditions, for example as described in the historian of science A. Crombie's *Styles of Scientific Thinking in the European Tradition.* Styles of scientific thinking have some similarities to Kuhn's paradigms, but in contrast to Kuhn's paradigms, who succeed each other through history, Crombie's styles coexist. He distinguishes between six styles of scientific thinking (Crombie, 1994, Vol. I, 83ff). Each style arises at a certain time, it is more or less widespread at different times, and it changes through history.

Crombies style of scientific thinking is not the same as a scientific tradition. However, "scientific tradition" is not a strict concept. The point is to show that there are alternatives to the unity of science. For my purpose, the division into three scientific traditions is sufficient, and I will now indicate why they are important.

After the scientific revolution the Platonic tradition became more and more dominating. One reason is the promise that the new science and technology can realize what is sometimes called the "Cartesian dream", according to which we will "… make ourselves, as it were, the masters and possessors of nature" (Descartes, 1971, 78). Although we should not underestimate the accomplishments of modern science and technology, we only have to keep the visible effects of climate change (extreme precipitation and floods, heat waves, hurricanes etc.) in mind to understand that the Cartesian dream will not be realized.

Environmental pollution and man-made climate change are, besides nuclear war, the greatest threat to humanity. One of the pioneers of modern ecology, Barry Commoner, has argued that to solve today's environmental problems we need a deeper understanding of the origin of the crisis. I cannot go into details, but I will emphasize that his ecology is holistic, in the Aristotelean tradition.[17] Looking at the whole, it becomes clear that there is no technical solution to these problems. Of course, that does not mean that we should not develop technology. On the contrary, it is crucial that we use science and technology to address today's environmental problems, but they must be subordinate to environmental thinking (Cf. Lubchenco, 1998).

[17] Cf. the second chapter, "The Ecosphere", of *The Closing Circle.* (Commoner 2020, 12–43).

There is another threat, though. In 2014 the physicists Stephen Hawking, Max Tegmark and Frank Wilczek, and the computer scientist Stuart Russell, published an article in which they warned against what the development of artificial intelligence may lead to. In the article they said, among other things: "Success in creating AI would be the biggest event in human history. Unfortunately, it might also be the last, unless we learn how to avoid the risks" (Hawking et al. 2014). Other reseachers and entrepreneurs have followed up.[18]

Some focus on the dangers of artificial intelligence, but many see opportunities. Max Tegmark, president of Future of Life Institute, refers to a late night discussion with Larry Page, co-founder of Google. According to Tegmark, Page gave "a passionate defense of the position I like to think of as digital utopianism." This position entails that digital life is the natural and desirable next step in the cosmic evolution, and if we let digital minds be free, the outcome is almost certain to be good (Tegmark, 2017, p. 32). Page's vision is widespread among leading figures in Silicone Valley (Lanier, 2013).

Regardless of what one focuses on, the opportunities or the dagers, there is no doubt that artificial intelligence raises some fundamental questions. The most fundemantel question is: "What is man?" And this is the basic question of the humanities.

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[18] In 2023 Future of Life Institute published a similar letter first signed by some prominent scientists, sholars and entrepeneurs and later signed by thousands of researchers. See https://futureoflife.org/open-letter/pause-giant-ai-experiments/ (accessed 15.6.2023).

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