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THE ORIGINS OF WESTERN THOUGHT

REVIEW

# Review of Sattler, Barbara M. *The Concept of Motion in Ancient Greek Thought* (2020) & Reply

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# Review of Barbara M. Sattler. *The Concept of Motion in Ancient Greek Thought: Foundations in Logic, Method, and Mathematics*. Cambridge: Cambridge University Press, 2020, 450pp., ISBN 1108477909.

Barbara Sattler's book promises to tell us the history of how the phenomenon of motion became a subject matter of a rational discourse and advanced analysis between Parmenides and Aristotle. The story spans from the exclusion of motion from both what *is* and what can be *thought* by Parmenides to its inclusion among things that *are* and can be *thought* by means of logic and mathematics in Plato and Aristotle.

At the core of the story told in the book are Zeno's paradoxes of motion. While they had aimed at the refutation of the possibility for motion both to be thought and to be, they had constituted a conceptualisation of motion that turned out to be a fruitful challenge for those looking to prove the opposite on both charges. The atomists took some important steps to this effect, particularly by introducing the notion of void as a physical substitute to the Parmenidean not-Being, thus allowing both for plurality of entities and for motion. However, their theoretical assumptions, particularly the indivisibility of atoms, were not sufficient to invalidate Zeno's paradoxes. More advances were made by Plato. He worked out logical means for thinking what 'is not' in terms of difference, thus smoothing the path to rationalising motion. Moreover, he offered a mathematical theory of time as a measure of motion. But in failing to provide a consistent theory of speed, as Sattler argues, Plato remained unable to dismantle Zeno's paradoxes. This achievement was reached only by Aristotle due to his theory of the continuum. In making both motion and time infinitely divisible in thought by means of the distinction between actuality and potentiality, Aristotle successfully disabled the trap set by Zeno for Achilles. However, like Plato, Aristotle considered time to be the only measure of motion. This prevented him from measuring the speed of a given motion and thus to solve the paradox of the moving rows. While he was, unlike Plato, in possession of the conceptual means to arrive at the definition of speed in terms of the relation between distance covered and time taken, Aristotle nevertheless shrank from spelling it out and, consequently, from measuring motion by speed. The reasons for this failure lay, according to Sattler, partly in Aristotle's metaphysics and partly in his philosophy of mathematics. His conception of relation as a derivative category prevented him from taking a relation as a measure. Beside this, he was reluctant, like other mathematicians of his time, to coordinate numbers that do not stay for homogenous magnitudes (space and time in this case). Nor was he willing to free the numbers from their fundamentum in sensible things in a way the Platonists did. He thus stopped short of giving the definition of speed as well as of making speed the measure of motion.

While the story told in the book no doubt constitutes an important thread in the process of conceptualising motion that took place starting with Parmenides and culminating with Aristotle, one may ask whether it is the full story and whether the thread picked up is the main one. Sattler is no doubt right in stressing the importance of the developments in logic, methodology, and mathematics which made it possible to conceive of motion as a phenomenon that can be grasped conceptually. The path followed in retracing this process, however, is determined by the goal to be reached which is measuring speed. The emphasis thus lies on making motion measurable. Measuring motion is no doubt a way how to make it graspable by rational means. Moreover, it is the link which connects ancient philosophy with modern mathematical physics. But one may argue that measuring motion is not the main target ancient natural philosophy aims at in conceptualising motion. While measuring certainly enables us to grasp aspects of motion by rational means, it does not answer the fundamental question what motion is. This is a question both Plato and Aristotle are highly interested in, so much so as they offer elaborate theories in which measuring motion plays only a part, more important in Plato than in Aristotle, after all. These theories involve answers to questions such as what kinds of objects are affected by motion, what motion does with them, how it comes about, how many kinds of motion there are, etc. Most importantly, these theories try to conceptualise motion not only insofar as it can be measured but more fundamentally insofar as motion is change.

What I mean can be best shown on Aristotle's own definition of motion. 'Motion,' he tells us, 'is actualisation of what is potentially insofar as it is potentially, e.g. changing in quality of what can change in quality insofar as it can change in quality, growing and shrinking of what can grow and of its opposite, what can shrink (…), coming to be and passing away of what can come to be and pass away, locomotion of what can move along' (*Phys.* 3.1 201a10-15). To understand this definition, we need to know what Aristotle's concept of the actualisation of a potentiality means, namely something acquiring a form it did not possess before, but it had been susceptible to acquire having had another form. It is a process of becoming qualified or formed in a particular way, a process made possible by the fact that particular determinations or forms are susceptible to yield to the opposite ones. This is what motion is about according to Aristotle.

What becomes affected by motion are material substances, i.e. things that are susceptible to change in their properties, either so that they nevertheless retain a basic form which makes them what they are or so that they cease to be what they have been and become transformed into other things. On the whole, in Aristotle's eyes, motions are different kinds of changes resulting in definite forms of particular substances. As such they are processes which make these things what they actually are. This is why motion is a fundamental concept in Aristotle's philosophy of nature but also why it overlaps with his metaphysics.

Because Aristotle thinks that a form is a quality, he does not seek to define motion in terms of quantity. Sure, motions of substances can be measured, and as such it is a theoretical matter in which Aristotle is interested too. But what is measured, i.e. counted, is only an aspect of motion, singled out by a mental operation of ours. It is not motion *qua* motion. This is why conceptualising motion, for Aristotle, cannot be reduced to measuring motion.

Plato's conception of motion is more complex. There is no general definition of motion such as in Aristotle. But there is a multi-layered inquiry into the question of how to conceive of motion. One part of it are considerations on motion *qua* change taking place because of interaction between things acting and being acted one upon another. According to this theory, there is motion where there is a ποιεῖν–πάσχειν relationship. However, if everything was constantly acting and being acted upon, without anything remaining the same, or one, i.e. without anything standing out of these processes, there would be nothing upon which our thinking could lean in its endeavour to grasp these processes rationally. This line of thought is most forcibly drawn in Plato's *Theaetetus*, but it is equally present in the *Cratylus*, in the *Sophist*, and in the *Timaeus*. Consequently, another part of Plato's inquiry into the theory of motion deals with the question whether there are, within these processes themselves, some recurrent patterns or even some constant elements our thinking can rest upon. This is what Plato presents in the *Timaeus*. The recurrence of the movements of heavenly bodies makes it possible to count them and thus to establish quantitative measures of motion in terms of time. This, however, is not enough to make accessible to reason the changes which take place without a regular recurrence characteristic of uniform circular motions. If other processes of change – not only other types of locomotion but also changes in quality, processes of growth and shrinking, of coming to be and passing away – are to be graspable by rational means, they are supposed to occur on the basis of a number of invariable elements of a definite geometrical shape and size, the combinations of which allow in theory to conceive of all differences perceptible by our senses in mathematical terms. In the *Timaeus*, Plato works out both these theories, that of the measurement of the circular motions of heavenly bodies as well as that of the measurement of all other processes of change taking place within the perceptible world.

Fascinating though it is, this project of mathematical physics is not the whole of Plato's theory of motion. Like in Aristotle, in Plato too, measuring motion by mathematical means does not tell us what motion is. To address this question, Plato distinguishes between two fundamentally different kinds of motion: self-motion and motion induced in one thing by another thing. The first kind of motion, according to Plato, is that of souls and souls only. The second one is that of bodies. In the *Phaedrus* (245c-e) and in the *Laws* (893b-897a), we are told that self-motion is the definition, or the very essence, of the soul and that all motions of bodies go back to the self-motion of the soul. In the *Timaeus* (48e-53b, 57d-58c), a partly different theory is put forward according to which the motion of bodies arises whenever things that are not homogeneous come into contact one with another. According to this latter theory, this is what happens to the sensible images of the intelligible Forms that come into being due to the existence of place (τόπος) or space (χώρα) which is receptive (δεχομένη) of such images.

We need not to go into the details of these passages here. Nor do we need to solve the problem of how to square them one with another. Suffice it to say that Plato searches for an explanation of motion in terms of the kinds of things affected by it, of its cause and of its function. In contrast to Aristotle, but closer to some Presocratics, particularly Empedocles (a prominent theorist of motion, by the way), he conceives of two kinds of motion, one of which, that of the soul, is teleological in nature due to the capacity of the soul's circular motion to grasp intelligible patterns and imitate them by means of recurrence while the other, that of the constituents of bodies, lacks the orientation towards the goals and is disruptive of regularity. On Plato's account, however, the former has an upper hand over the latter so that, on the whole, motion is, for Plato as for Aristotle, explanatory of how the world of change becomes structured by regular patterns. Such an explanation is, in my view, what the concept of motion in Plato and Aristotle aims at.

This is my general objection to Barbara Sattler's otherwise most valuable book on the concept of motion in ancient Greek thought. It narrows the scope of ancient theories of motion to the question of its measurement.[1]

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Let me add a remark on a particular point concerning Sattler's understanding of Plato's *Timaeus*. The author claims (p. 269-270, n. 74) that, in the theory of planetary motions put forward in this dialogue, Plato nowhere states that the circles of the sun, Venus and Mercury are different of length. Referring to the *Timaeus* 38d, Sattler says that "nothing suggests here that Plato is not assuming these three circles to be of the same size". According to the *Timaeus* 36d2, however, the Demiurge divided the Cercle of the Different of the World Soul into "seven uneven circles" (ἑπτὰ κύκλους ἀνίσους). This plainly means that each of them is of a different length, otherwise there would not be "seven uneven circles". Since these circles are the orbits of the seven planets (*Tim.* 38c5-d1), the orbits of the sun, Venus and Mercury (*Tim.* 38d2-6) must be different of length. Moreover, the Circle of the Different is said to have been split "six times according to each interval of the double and the triple, these intervals being three in each case" (ἑξαχῇ ἑπτὰ κύκλους ἀνίσους κατὰ τὴν τοῦ διπλασίου καὶ τριπλασίου διάστασιν ἑκάστην, οὐσῶν ἑκατέρων τριῶν, *Tim.* 36d2-4). This is a reference back to the description of the two series of intervals of which the one corresponds to the first three square numbers while the other to the first three cube numbers (*Tim.* 35b4-c2). Hence, the diameters of the seven planetary orbits correspond to the numbers 1, 2, 3, 4, 8, 9, 27 (on different ways to interpret this correspondence see Heath, 1913, p. 164). While the *Timaeus* does not tell us which one of these orbits is that of Venus and which one that of Mercury (with the moon occupying the first and the sun the second orbit from the Earth, *Tim.* 38d1-2), it leaves no doubt about the different size of these orbits.

All of this is about size and length, not about motion and speed. However, this being so it cannot be the case that the sun, Venus and

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[1] For a broader approach to the history of the concept of motion in Greek philosophy, with a focus on Aristotle, see Patočka (2011).

Mercury complete their orbits at the same time (in a solar year) because they move with the same speed (as we are told in *Tim.* 38d3) around the orbits of the same size (as Sattler argues for, p. 269-270). Something more is wrong in Sattler's account on Plato's theory. Most likely, it is the claim according to which, for Plato, speed is determined only by the length of the path a planet travels so that "the body with the spatially smaller orbit is *for that reason* faster than the one with a larger orbit, because it has a smaller task to complete" (p. 271, the emphasis is Sattler's). Given the fact that, according to the *Timaeus*, the orbits of the sun, Venus and Mercury are of different sizes (*Tim.* 36d2-4), that these three planets complete their orbits at the same time (*Tim.* 38d3) and that three of the seven orbits move "with similar speed" (τάχει … ὁμοίως, *Tim.* 36d5) while the remaining four revolve each with a speed different from all the others (*Tim.* 36d5-6), the most economical way how to save these textual phenomena is to interpret "with similar speed" as referring to the same – or nearly the same – *angular* velocity of the orbits of the sun, Venus and Mercury. This is the interpretation given by Cornford (1935, p. 82-87) which Sattler rejects (p. 271-272). [2]

As Cornford (1935, p. 82) remarks, in the *Laws* 893c-d, Plato describes the capacity of the circular motion to "distribute itself proportionally to the smaller and the bigger circles, thus being itself proportionally smaller and greater" (ἀνὰ λόγον ἑαυτὴν διανέμει σμικροῖς τε καὶ μείζοσιν [*sc.* κύκλοις], ἐλάττων τε οὖσα καὶ πλείων κατὰ λόγον, *Leg.* 893d1-2). "This," the Athenian Stranger says, "has become the source of all the marvels, since it bestows on big and small circles corresponding low and high speeds, something one would believe is impossible to happen" (διὸ δὴ τῶν θαυμαστῶν ἁπάντων πηγὴ γέγονεν, ἅμα μεγάλοις καὶ σμικροῖς κύκλοις

[2] The same interpretation in terms of angular velocity is found in Heath (1913, p. 165; 1921, vol. I, p. 311), Dicks (1970, p. 123) and Vlastos (1975, p. 34). Dicks' and Vlastos' criticism of Cornford (Dicks, 1970, p. 124-129; Vlastos, 1975, p. 58-59) does not concern this particular point on which they all agree with Heath. For a more recent summary of the discussion on the astronomical passage in the *Timaeus* see Ferrari/Petrucci (2022, p. 466-473) with further references.

βραδυτῆτάς τε καὶ τάχη ὁμολογούμενα πορεύουσα, ἀδύνατον, ὡς ἄν τις ἐλπίσειε, γίγνεσθαι πάθος, 893d2-5).

When Plato speaks, in the *Timaeus*, about lower and higher speeds assigned to circles of different sizes, have we to suppose that he attributes the lower speed to the greater circle and the higher speed to the smaller one because, for him, "speed is determined only by the length of the path a planet travels", as Sattler assumes (p. 271)? For what reason would he have done so? Let us take the simple case of several objects placed on the potter's wheel at different distances from the centre and carried around. The wheel will bring them back to their starting points at the same time, though those more distant from the centre on a longer path. In the *Timaeus*, Plato notoriously says that to explain the complexity of planetary motions without the help of visual representation would be an effort spent in vain (44d2-3). Hence, it is hard to believe that he did not make the much simpler observation of the things placed on the potter's wheel. But if he did so, he must have attributed, in the passage just quoted from the *Laws* 893c-d, a higher speed to the greater circle, and *vice versa*, in terms of a given distance covered in a certain time. My conclusion is that if, in the *Timaeus* 39a2-3, Plato attributes a higher speed to the planets revolving in smaller circles and the lower speed to those revolving in greater circles, it is *not because* the first cover a smaller and the latter a longer distance, as Sattler presumes, *but despite it*. The reason is not the length of the path a planet travels but the fact that the orbits of the planets have been endowed with different angular speeds (36d-7): the moon with the highest one, the sun, Venus and Mercury jointly with a lower one than the moon but still a higher one than Mars, Jupiter and Saturn, each of these latter three moving with its own angular speed, slower than the four other planets.

The passage from the *Laws* about the marvels of the concentric circles moving with one and the same motion is echoed, as it were, by pseudo-Aristotelian *Mechanics*. Here we read: "Since no two points on one and the same radius travel with the same speed (ἰσοταχῶς), but of two points that which is further from the fixed center travels more quickly (θᾶττον), many marvellous phenomena (πολλὰ τῶν θαυμαζομένων) occur in the motions of circles, which will be demonstrated in the following problems" (*Mech.* 848a15-19, translation by E. S. Foster). This text is explicit on the outer circles moving faster and the inner circles moving slower in terms of a distance covered in a time: "[W]e use the word 'quicker' (θᾶττον) in two senses; if an object traverses an equal distance in less time (ἄν … ἐν ἐλάττονι χρόνῳ ἴσον τόπον διεξέλθῃ), we call it quicker, and also if it traverses a greater distance in equal time (ἐὰν ἐν ἴσῳ πλείω). Now the greater radius describes a greater circle in equal time; for the outer circumference is greater than the inner" (*Mech.* 848b5-9, translation by E. S. Foster).

Speed in terms of the relation between time taken and space covered was a topic discussed since the times of Plato's *Laws* at latest. It figured under the header of the marvels of moving concentric circles.

## Reply

I am very grateful that Filip Karfik took the time to read through my book carefully and to comment on it. His reply opens up further points of importance for the development of the concept of motion; in particular, he makes it clear that we have a much less unified account of motion in Plato than we have in Aristotle. My reply will respond to his two main points of criticism of my book, (a) that I give only a quantitative account of motion and (b) that I misunderstand Plato's account of speed in the *Timaeus*.

(a) Filip Karfik claims that I focus merely on a quantitative account of motion which is not the main point for ancient philosophers. This criticism comprises three sub-points: first, that especially Aristotle has a qualitative account of motion for which measuring, and thus a quantitative account, is not important; second, that in contrast to the assumption in my book, measuring is not the goal to be reached in ancient accounts of motion; and finally, that a focus on the measure and the quantitative side does not answer the question what motion is.

That Aristotle has a qualitative account of motion is a common assumption in the secondary literature,[3] and a claim I touch upon in the introduction of the book. I am by no means denying this qualitative side. But this standard story about Aristotle account of motion leaves out the quantitative side of his understanding of motion, a side which is also fundamental to our modern scientific understanding of motion.[4] Scholars usually pay no attention to the enormous amount of conceptual work Aristotle does on the quantitative side, which can, for example, be seen from the fact that he provides us with the first theory of measurement in Western thought in his *Metaphysics* I; due to this lack of scholarly attention, this treatise is very much understudied in Aristotelian scholarship.[5] By contrast, my book draws attention to the amazing resources Aristotle provides in this respect as precursor to measuring motion and to our seemingly natural concept of speed.

Furthermore, Karfik claims that measuring motion is not the main target for the ancient philosophers conceptualising motion. I agree with Karfik, but in fact I do not claim measuring motion as the main target of ancient natural philosophy in my book nor do I investigate the measurement of motion as such. (This can be seen, for example, from the fact that there is no discussion of measuring devices at all, even though this would also be a very interesting endeavour with respect to motion, given that it is exactly in the 4th century BCE that we find the first sun-dials in Greece[6]). Rather, for

[3] See, for example, Kuhn (1977 p. XI-XII).

[4] The standard story often claims Aristotle's account to be merely qualitative, since there are no quantitative predictions, e.g. where and when to find a planet in its revolution. This is assumed to be overturned by Descartes and his quantitative approach that paves the way to modern science, which is quantitative. Such a story works with a reductive understanding not only of Aristotle's work, but also of what the quantitative aspect of science amounts to.

[5] See Sattler (2017).

[6] Cf. Schaldach (2021).

a full understanding of Aristotle's account of motion *the conceptual preconditions* for measuring motion and speed are central and these the book attempts to uncover. One important point, that scholars usually do not notice, is that we do not have the conceptual set-up for measuring speed and for fully understanding speed in ancient times before Aristotle.

By taking these conceptual preconditions for measuring motion and speed into account it becomes clear that motion requires a certain relation of time and space. (Note that I am thus not making a metaphysical claim (such as that time is more fundamental than motion, as this is not the case for Aristotle), but a conceptual one – in order to get clear about the concept of motion we need to understand the relation of time and space). Understanding that motion requires a certain relation of time and space is an insight that forms also an important part of the answer to the question that Karfik raises, namely "what is motion?". It clarifies what motion is more than if we say, as Karfik does, that "motions are different kinds of changes resulting in definite forms of particular substances. As such they are processes which make these things what they actually are", which leaves us with an unclear relationship of motion, change, and processes. Karfik's account of Aristotle's understanding of the *kinêsis* of something in terms of this something acquiring a form it did not possess before, but had the potential to possess, is of course important for the general understanding of *kinêsis* in Aristotle (even if I would not agree with Karfik's equation of form with a quality). It directly takes up Aristotle's definition of *kinêsis* in *Physics* III as the "actualisation of what is potentially in so far as it is potentially" that unfortunately I could deal with only on a few pages in the book. But for locomotion specifically, which is the ultimate focus of the book, it is central to figure out why Aristotle does not understand it in terms of time and distance covered. Surprisingly, while Aristotle has developed the conceptual tools for fully understanding speed, he does not account for speed in terms of time and space, and the book attempts to sketch an explanation for this fact.

The book sketches the two main problems that locomotion raises for ancient philosophers: first, the ontological challenge that *kinêsis* requires what is and what is not to be connected: something is first F and then not F any longer, is first here and then not here any more, a problem raised by Parmenides; and second, the spatio-temporal problem that an understanding of locomotion requires time and space to be brought together, a problem raised by Zeno. While Aristotle considers the first problem to be solved, he does no really solve the second problem inspite of having the tools to do so.

(b) Moving on to Plato now, Karfik's main argument against my interpretation of Plato's conception of speed in the *Timaeus* contains the following steps:

(1) According to Karfik, the Platonic text should be understood as claiming that *all* of the seven circles in which the heavenly bodies are situated necessarily have different length.

(2) Consequently, it is not the case according to the *Timaeus* that the Sun, Venus and Mercury complete their orbits at the same time because they move with the same speed around orbits of the same length, as I suggest in my book.

(3) Rather, it must be that these heavenly bodies complete their orbits at the same time, because they possess the same angular velocity, i.e. they cover the same angle in the same time.

(4) *Laws* 893c-d, which describes the motion of a disc, like a potter's wheel, claims that a point further out on the disc will cover a bigger circle, while a point further in a smaller circle. Since both points will be back at the position where they started at the same time, the one revolving in a larger circle will move with higher linear speed than the one covering a smaller circle.

(5) Since we find this understanding of different speeds on a disc in Plato's *Laws*, we would expect Plato also to ascribe a higher speed to larger circles in the cosmology of the *Timaeus*. Given that we find the opposite in the *Timaeus*, the reason for Plato ascribing a higher speed to the smaller circles and a lower one to the larger circles is that the orbits have been *endowed with different angular speed*.

Let me start by replying to Karfik's first point (steps (1) – (3)) that allegedly the circles of the Sun, Venus, and Mercury cannot be of the same size according to the text in the *Timaeus*. All that the text (36d2) in fact claims is that the demiurge divides the Circles of the Different into seven *anisos* (uneven, unequal) circles, which does not necessarily mean that they are of different length: He split "the inner [band] six times into unequal circles corresponding to each of the double and triple intervals, there being three intervals in each case" (τὴν δ'ἐντὸς σχίσας ἑξαχῇ ἑπτὰ κύκλους ἀνίσους ἑξαχῇ ἑπτὰ κύκλους ἀνίσους κατὰ τὴν τοῦ διπλασίου καὶ τριπλασίου διάστασιν ἑκάστην, οὐσῶν ἑκατέρων τριῶν, 36d2-4). *Anisos* is a rather broad characteristic. It can indicate differences in size, but this is only one among a range of differences. The text does not say that they are of unequal *size*, and so the circles may be unequal, for example, in their tilting. (The correspondence to the double and triple intervals refers back to the way in which the mixture of Being, Sameness and Difference is split up – how exactly this is tied back to the length of the diameter of the circles is left open by Cornford and Heath; and we should not forget that the intervals in question here, 1:2 and 2:4 and 4:8 on the one hand and 1:3 and 3:9 and 9:27 on the other hand, will give us the same ratio each). Now Plato does indeed explicitly claim that some planets "move in a larger circle, others in a smaller one", and that the Moon is situated in the first circle from the earth (and thus presumably in the smallest circle), the Sun in the second from the earth (38c9-d1). While Plato thus clearly indicates the circle of the Moon and of the Sun to be of different size, he interestingly switches his description when he comes to Venus and Mercury in the following lines (38d2-3). Instead of telling us in which circle from the earth they are situated, he claims them to be "set to run in circles that equal the Sun's in speed" (so also in 36d5). So, while some circles are said to be of different size, this is not claimed to be the case for the three heavenly bodies Mercury, Sun, and Venus. Thus, we cannot simply state, as Karfik does, that the text quoted above "plainly means that each of them is of a different length, otherwise there would not be 'seven uneven circles'". All we are told so far is that the orbits of *some* heavenly bodies are of different length, like the one of the Moon and of the Sun, and those are also given different speeds. And then we have three heavenly bodies which move with the same speed. While also their circles are unequal, we get no indication that they are of different length. According to Plato, the revolutions of the Sun, Venus, and Mercury share the same periodic time,[7] which I suggest in the book, results from their covering circles of the same distance.[8]

But this discussion leads to an additional complication about Mercury, Venus and the Sun moving with similar speed. The main issue is how Plato thinks of speed in the *Timaeus*. And here Karfik thinks that Plato is well aware of speed being a combination of time and distance covered from cases like the potter's wheel. To see whether this is true, we should look at the way how the *Timaeus* understands the relation between the size of the circles in which the heavenly bodies move and their speed when he claims, for example, that "[some planets] would move in a larger circle, others in a smaller one, the latter moving more quickly and the former more slowly" (39a2–4).

In order to explain the question how size and speed are related in Plato, Karfik refers to what we can call the potter's wheel problem, which can be found in *Laws* 893c-d as well as in the pseudo-Aristotelian *Mechanica*, what I named step (4) and (5) above. It is very interesting that Karfik brings in the discussion about different speeds on a disc and I should have mentioned them in the book. But I wonder whether it is indeed useful to refer to it for the interpretation of the *Timaeus*, since the claim in the *Timaeus* is the inverse of what we would expect from the potter's wheel example, as Karfik and I both agree: following the potter's wheel example, where a point on the outer rim has to travel faster than one on the inner part, since it covers a greater circle in the same time, we should expect Plato to claim that the outer planets move faster in their bigger circles than

7 So also Cornford (1935, p. 105 ff.) and Calcidius ad locum.

8 Since the circles are first and foremost geometrical circles, there is no need to have them staggered.

the inner planets in their smaller circles. But this is *not* what we find in the *Timaeus*. On the contrary, we are told in the *Timaeus* that the planets in the outer, bigger circles move slower than the ones in the smaller, inner circles.

Rather than dropping the relation to the potter's wheel, Karfik makes a rather dangerous argumentative move: since what we find in the *Timaeus* is the inverse to the *Laws*, ERGO, Karfik concludes, Plato must talk about angular speed there. Spelt out a bit more fully: since Plato in the *Laws* understands speed as linear speed along the lines we do (so that something covering more distance in less time is faster), the fact that he does not account for speed in this way in the *Timaeus*, but claims the bodies further out to be slower, shows that he simply endows them with different angular speed. This conclusion seems to be doubly problematic to me: first, Karfik claims that the *reason* for the heavenly bodies moving with different speed is that they have been *endowed* with different speed, which does not seem to be what we could properly call a reason: why are the outer planets slower? Because they have been made to be slower – hm. Secondly and more importantly, I do not see that Plato talks about angular velocity in the *Timaeus*. The potter's wheel discussion does not suggest anything about different angular velocities (in fact a point far out on the wheel and one further in will have the same angular velocity, since both cover the same angle in the same time). And the fact that Plato talks about the *size* of the circles when talking about differences in speed in the *Timaeus* (see 39a2-4), clearly suggests that he is not talking about angular velocity, but rather reducing speed to time taken: the larger a circle a planet has to cover, the longer it will take him to complete a circle and thus the slower it is in finishing its tasks of completing its circle. This reading is also supported by the fact that Plato claims the three *circles* of the Sun, Venus, and Mercury to have the same speed, not these heavenly bodies themselves or their motions (38d2-3; similarly, *Epinomis* 986e). Accordingly, it is the size of the circle that determines the speed: circles of the same size 'have the same speed', since something that moves with constant speed, will cover them in the same time.[9] Plato does not work with the concept of angular velocity, for there the size of the circle would not matter, but rather with a more basic notion, which I described as 'time in which a thing accomplishes what it is supposed to'.

Given that we find an understanding of something being faster as covering more distance in the same time only in the *Laws*, but not in the *Timaeus*, it seems much more likely to me that Plato does in fact not yet have an account of speed inspired by the potter's wheel in the *Timaeus*. While the *Timaeus* displays a much deeper understanding of motion than earlier dialogues (e.g., we get a more positive account of the visible motions of the heavenly bodies; we find two fundamentally different kinds of motion – motions of the soul versus motions of the body), an account of speed along the lines we understand it today is not among the developments we find in the *Timaeus*. Plato's discussion of "speed" of the heavenly bodies solely takes the time taken into account, not the different distances; like his predecessors, Plato is reducing speed to time.

Not only Plato, but also Aristotle claims the outer planets to be moving slower than the inner ones – and we should not be surprised about this, since this also fits the phenomena, which we nowadays explain by the decreasing strength of the gravitational force of the celestial centre.[10] So both Plato and Aristotle claim the inverse of what we would expect from a potter's wheel. But in contrast to Plato, we find an explicit explanation in Aristotle why the different distribution of speed among the heavenly bodies is invers to what we would expect from the potter's wheel example: in *De Caelo* II,10 Aristotle assumes that while the planet furthest out is in principle swiftest (as we should assume from the potter's wheel), in fact it

[9] Also, Aristotle connects Venus and Mercury in a similar vein when he claims in his *Metaphysics* 1073b 30ff that Venus and Mercury have the same poles with respect to their third sphere (while they share the first two sphere, as all planets do, with Sun and Moon).

[10] Of course, Jupiter and the Moon also differ in their angular velocity, both in a heliocentric and in a geocentric world view, since it requires Jupiter much longer to cover a certain angle.

moves at the slowest pace (thus going against the potter's wheel). The reason for the planet furthest out to be slowest is that it is situated closest to the outermost revolution of the heavens, which goes swiftest and in opposite directions; thus it is most affected by this opposite motion.[11] The fact that Aristotle explicitly shows that and why the differences in speed of the motions of the heavenly bodies do not fit with what we would expect from the motions of a disc, shows that in between the *Timaeus* and Aristotle's *De Caelo* the potter's wheel has become much more present on the philosophers' mind.[12]

What I found important in the *Mechanica* for our topic is that fastness is said to be used in two ways according to the quotation given by Karfik: "the word quicker is used in two senses, if an object traverses an equal distance in less time, we call it quicker, and also if it traverses a greater distance in equal time." Interestingly, these two ways of capturing differences in speed are not seen by the author of the *Mechanica* as expression of one concept of speed; instead, there are *two senses of quicker*. This suggests that the author of this treatise does not have a unified account of speed; rather, if we take the distance fixed and compare different times required to cover this distance, this is a different sense of fastness than if we take the time fixed and compare the different distances that can be covered in this time.

Thus, while a discussion of speed in terms of time and space may be on the table since Plato's *Law*, as Karfik claims (which does not need to be earlier than at least parts of Aristotle's *Physics*), we see in the *Mechanica* that we do not yet have a unified concept of speed.

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[11] For a possible connection between this explanation and the work of Eudoxus, see my book p. 388.

[12] Given the frequency with which Plato refers to pottery in his work, I agree with Karfik that we should assume Plato to be familiar with a potter's wheel. But none of Plato's references mentions the potter's wheel with respect to different speeds on the disc, and being familiar with the tool does not yet mean he had taken up what we called the potter's wheel problem for his considerations about speed before the *Laws*.

And to show the steps to such a unified account of speed is part of what I try to do in the book.

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