Why Continuous Motions Cannot Be Composed of Sub-motions:

Aristotle on Change, Rest, and Actual and Potential Middles

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Abstract:

I examine the reasons Aristotle presents in *Physics* VIII 8 for denying a crucial assumption of Zeno's dichotomy paradox: that every motion is composed of sub-motions. Aristotle claims that a unified motion is divisible into motions only in potentiality (δυνάμει). If it were actually divided at some point, the mobile would need to have arrived at and then have departed from this point, and that would require some interval of rest. Commentators have generally found Aristotle's reasoning unconvincing. Against David Bostock and Richard Sorabji, inter alia, I argue that Aristotle offers a plausible and internally consistent response to Zeno.

I defend Aristotle's reasoning by using his discussion of what to say about the mobile at boundary instants, transitions between change and rest. There Aristotle articulates what I call the **Changes are Open, Rests are Closed Rule**: what is true of something at a boundary instant is what is true of it over the time of its rest. By contrast, predications true of something over its period of change are not true of the thing at either of the boundary instants of that change. I argue that this rule issues from Aristotle's general understanding of change, as laid out in *Phys.* III. It also fits well with *Phys.* VI, where Aristotle maintains that there is a first boundary instant included in the time of rest, but not a "first in which the mobile began to change."

I then show how this rule underlies Aristotle's argument that a continuous motion cannot be composed of actual sub-motions. Aristotle distinguishes potential middles, points passed through en route to a terminus, from actual middles. The **Changes are Open, Rests are Closed Rule** only applies to actual middles, because only they are boundaries of change that the mobile must arrive at and then depart from. On my reading, Aristotle argues that the instant of arrival, the first instant at which the mobile has come to be at the actual middle, cannot belong to the time of the subsequent motion. If it did, the mobile would already be moving towards the next terminus and thus, per *Phys.* VI 6, would have already left. But it cannot have moved away from the midpoint at the very same moment it has arrived there. This means that the instant of arrival must be separated from the time of departure by an interval of rest. I show how Aristotle's reasoning applies generally to rule out any continuous reflexive motion or continuous complex rectilinear motion. On my interpretation, however, the argument does not apply to every change of direction. When, as in the case of projectile motion, multiple movers and their relative powers explain why the mobile changes directions, distinct sub-motions are not involved. Aristotle holds that such motions cannot be continuous, not because they involve intervals of rest, but because they involve multiple causes of motion. My interpretation of the **Changes are Open, Rests are Closed Rule** allows us to make better sense of Aristotle's argument than any previous interpretation.

A. Zeno's Dichotomy Paradox and Aristotle's Two Responses

The paradoxes of Zeno of Elea offer some of the most intriguing arguments against motion ever made. Aristotle discusses four of Zeno's paradoxes in his *Physics*. Each of these paradoxes derives some impossibility from the assumption of motion. Zeno's first paradox, the dichotomy paradox, purports to show that in order for a mobile to complete any motion it must go through the infinite. Completing a motion requires going through an infinite number of half-distances, but this is impossible in any finite time, so motion is impossible. If Socrates walks up from the Piraeus to Athens, he must first go half the distance. Before going half the distance, he must go through half of the half and so on ad infinitum: Socrates will have to go through infinite half-distances in order to get from the Piraeus to Athens. Every motion requires going through the infinite, since in each case one must go through all the infinite half-distances. This is impossible in any given finite time, so motion is impossible in a finite time.[1]

Aristotle addresses Zeno's dichotomy paradox on three different occasions in the *Physics (Phys*). He mentions the dichotomy paradox at *Phys* VI 9, 239b10-14 only to dismiss it, referring back to VI 2 where he argued that the infinite half-distances within a given finite distance can be traversed in the given finite time. According to Aristotle, Zeno's paradox brings out an equivocation on the meaning of infinite. Continuous things are said to be infinite (ἄπειρον) in two ways. They can be called infinite "either according

[1] My formulation of this argument is based on Aristotle's discussion in *Phys.* VI 2, 233a12-21 and VI 9, 239b10-14.

[2] For further discussion of Aristotle on the infinite see Coope 2012 and Cooper 2016.

[3] Cf. B. Russell, *Introduction to Mathematical Philosophy* (London: 1919); A. Grünbaum, *Modern Science and Zeno's Paradoxes* (Middletown, CT, 1967); W. C. Salmon, *Zeno's Paradoxes*, 2nd edn. (Indianapolis: 2001).

See G. Vlastos, 'A Zenonian Argument against Plurality', in *Studies in Greek Philosophy*, i. *The Presocratics* (Princeton, 1993), 219-40 [originally in J. P. Anton and G. L. Kustas (eds.), *Essays in Ancient Greek Philosophy* (New York, 1971), 119-44] for an important statement of the to division or with respect to their limits" (*Phys* VI 2, 233a25-6). Continuous things are said to be quantitatively infinite when they do not have limits, as a line is said to be infinitely long when its length is not limited. They are said to be infinitely divisible when their continuous quantity can always be subdivided. A quantitatively infinite distance cannot be traversed in a finite time, but the infinite half-distances within the finite distance from the Piraeus to Athens can be traversed in a finite time since "time itself is also infinite in this way" (*Phys* VI 2, 233a29). Even if the distance from the Piraeus to Athens were to be infinitely divided, the journey of Socrates would still take two hours since the time of the journey would be infinitely divided in exactly the same way as the length.

Thus Aristotle's first response is to say that the paradox dissolves once one distinguishes between these two ways of being infinite. Magnitudes, motions, and times are infinite according to division (there is no limit to the number of divisions one can make in them), but they are not infinite with respect to their boundaries or limits.[2] Traversing a quantitatively infinite distance would be impossible in a finite time, but traversing an infinitely divisible distance is not a problem. However, Aristotle returns to the dichotomy paradox in *Phys* VIII and presents it in what he thinks is a more challenging form.

Here Aristotle brings out a difficulty implied in the notion of infinite divisibility, apart from any relation of time and distance. If we grant that, before a mobile can traverse a given distance, half the distance must be traversed and so on *ad infinitum*, then it will need to go through an infinite number of half-distances. If we number each of

[2] For further discussion of Aristotle on the infinite see Coope 2012 and Cooper 2016.

the half-distances the mobile goes through, “having gone through the whole, it follows that we will have counted an infinite number; and this, admittedly, is impossible.” (*Phys* VIII 8, 263a9-11) Aristotle then states that his earlier answer was dialectically sufficient, but did not reveal the full truth of the matter. (263a15-22) If there are an infinite number of times numbered, then this collection of times will itself be infinite. This would mean that motion would require going through or numbering infinite things, something Aristotle concedes is impossible in a finite time.

We can put the reformulated dichotomy paradox thus:

A) Any motion requires going through an infinite number of distances (since to traverse a given distance one must go through or number all its infinite half-distances, 263a5-10)
B) Going through an infinite number of distances is impossible in any finite time (an assumption Aristotle accepts, 263a10-11)
C) Any motion is impossible in a finite time (from A and B)

Contemporary thinkers have predominantly taken the structure of space and time to be atomistic, with time and space being composed out of dimensionless points, and they have responded to Zeno on this basis.[3] Their response is to deny premise B) by noting a mathematical fact: if we add all the half-distances together (1/2+1/4+1/8+…), their sum converges on the whole distance but will never exceed it. This suggests that the infinite number of half-distances could be gone through or numbered without taking an infinite time, making premise B) false.

[3] Cf. B. Russell, *Introduction to Mathematical Philosophy* (London: 1919); A. Grünbaum, *Modern Science and Zeno’s Paradoxes* (Middletown, CT, 1967); W. C. Salmon, *Zeno's Paradoxes*, 2nd edn. (Indianapolis: 2001).

See G. Vlastos, ‘A Zenonian Argument against Plurality’, in *Studies in Greek Philosophy*, i. *The Presocratics* (Princeton, 1993), 219-40 [originally in J. P. Anton and G. L. Kustas (eds.), *Essays in Ancient Greek Philosophy* (New York, 1971), 119-44] for an important statement of the arithmetical understanding of Zeno’s arguments.

Now Aristotle is aware of this fact about half-distances, as evidenced in *Phys* III 6, 206b3-11. He does not, however, make use of it in responding to Zeno. Consequently, those interpreters who think that Zeno's paradoxes are to be resolved by appealing to the mathematics of infinite series often find fault with Aristotle's response. However, as Pieter Sjoerd Hasper has argued, Zeno's paradoxes are best understood not as mathematical problems but as metaphysical ones.[4] Zeno's arguments rest on mereological claims: if the whole is nothing other than the sum of the parts and the parts are unlimited, then the whole must be unlimited in a similar way. We should not be surprised that Aristotle objects primarily to Zeno's metaphysics, not his mathematics. Aristotle's own metaphysical commitments concerning, inter alia, mereology, the nature of the continuous, and the infinite prevent him from straightforwardly endorsing the mathematical response to Zeno.[5]

[4] Pieter Sjoerd Hasper, 'Zeno Unlimited', *OSAP* 30 (2006), 49-85.

[5] To begin with, Aristotle denies that continuous entities are (or could be) composed out of indivisible parts (*Physics* VI 1, 231a21-232a22). In this respect, Aristotle's theory of the continuous resembles contemporary gunky theories, according to which continuous entities can be composed out of atomless gunk, which is always divisible into smaller parts (though on gunky theories these parts are all actual, whereas for Aristotle these parts are merely potential). Cf. J. Schaffer, 'Is There a Fundamental Level?', *Nous*, 37 (2003): 498-517); Dean Zimmerman, 'Could Extended Objects Be Made Out of Simple Parts? An Argument for "Atomless Gunk" ', *Philosophy and Phenomenological Research*, 56 (1996), 1-29.

Further, Aristotle rejects views of the continuity of motion that make time prior to motion, since in his view the dependency goes the other way. (*Physics* IV 12, 220b25-221b23; cf. IV 13) He also rejects reductive analyses of motion: motion is an incomplete and in process way of being that cannot be reduced to a sequences of times and locations (*Physics* III 3). For further discussion of the differences between Aristotle's conception of motion and contemporary at-at analyses, see Michael J. White, *The Continuous and the Discrete: Ancient Physical Theories from a Contemporary Perspective* (Oxford, 1992) 58-9 and 109-115.

Finally, Aristotle also famously denies that there can be anything that is infinite in a fully complete or actual way (*Physics* III 6-8). He does not think that I can do an infinite number of things in a finite time or complete an infinite series of tasks.

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While some commentators, such as KRS, have assimilated Aristotle's response to the mathematical one, Aristotle's rejoinder is, in fact, quite different.[6] Aristotle concedes that premise B) is true and attacks premise A).[7] Aristotle responds to the reformulated paradox by making a distinction: the mobile goes through the infinite in capacity (δυνάμει), but not in actuality (ἐνεργείᾳ).[8] Aristotle claims that premise A) is false when interpreted as requiring the mobile to go through an *actually* infinite number of distances.[9] Aristotle's final response to the paradox is to deny that a continuous motion can be made up of multiple actual sub-motions. The mobile only actually goes

[6] KRS acknowledges the distinction between two ways of reading premises 1) and 2) laid out in this paragraph, but they only discuss the *potentially* infinite formulation of the argument, where premise 2) is rejected (271). Thus their discussion ends up assimilating Aristotle's response to the mathematical response and fails to sufficiently consider why Aristotle rejects premise 1) when it is interpreted as speaking of the *actually* infinite.

[7] Since the classical modern conception formulates continuity in terms of being successively at infinitely many locations at infinitely many times, contemporary theorists using this conception of continuity are not in a position to deny A).

Further, many of them hold that B) is false even if there are an infinite number of motions separated by intervals of rest. Grünbaum, with the help of Friedberg, formulated the staccato run, a version of the dichotomy scenario on which the runner would complete an infinite number of tasks, pausing between each one for successively shorter times (Grünbaum 215-6). While some have claimed that such a run would not be consistent with classical dynamics (Burke 2000), others have defended it as both logically and physically possible by providing dynamic models that would satisfy what they take to be the relevant constraints. (Laraudogoitia 2006 and Lee 2013)

This points again to the significant differences between Aristotle's understanding of continuity and typical contemporary conceptions.

[8] I will sometimes use "actually" and "potentially" and cognates to translate ἐνεργείᾳ and δυνάμει and cognates, partly because these terms are easier to consistently render across cognates than exercise and capacity and partly because these terms are the standard English translations (via Latin usage). Nevertheless, I agree with Jonathan Beere in thinking that, for Aristotle, these two terms pick out different ways of being rather than signifying purely modal claims about capacity. Cf. Beere's discussion of *Met.* Θ 5 on being-in-capacity (2009, 152). So while I will use this language, I am understanding "potentially" and "actually" as making claims about different ways of being somewhere, not just different logical possibilities.

[9] If we instead take premises A) and B) of the reformulated argument to be speaking of a *potentially* infinite number of distances, not an *actually* infinite number, then Aristotle, in line with the mathematical response, would deny that premise B) is true (263b6-8). This formulation, however, is not significantly different from the original formulation because Aristotle takes the infinite divisibility of continuous quantities to imply a potentially infinite number of divisions (*Phys.* III 6, 206b4-19).

through one distance and performs one motion. Thus, Aristotle insists, there is no impossibility in motion (VIII 8, 263a23-263b8).

B. Overview

Aristotle's insistence that a continuous motion cannot be made up of actual sub-motions is crucial not just for his response to Zeno, but also for two other important claims made in this chapter. First of all, it is the key premise of Aristotle's strongest and most carefully laid out arguments for establishing that only circular motion can be everlastingly continuous (262a13-263a4). He also uses this claim about motion to criticize those natural philosophers who say that "all perceptible things are always moving." (265a3-4) For Aristotle, something cannot always be in flux: it must first complete a change (whether of place, alteration, or growth) and have a period of rest before beginning a new change. Thus Aristotle's views on this subject lie at the core of his picture of natural things as undergoing intrinsically goal-directed changes that have definite limits. Aristotle's cosmos is finite and the only endless motions it can contain are the everlasting circular motions of the heavens.

Aristotle introduces his core reasons for claiming that a continuous motion cannot be composed from a number of different motions earlier in *Phys* VIII 8. There Aristotle argues that when a motion is actually divided at some point the mobile must arrive at and then depart from this point and thus must rest. If this argument succeeds, one unified continuous motion cannot be composed out of multiple actual motions, since there would be intervals of rest in between, and a key premise of Zeno's reformulated argument would prove false. However, commentators, including Richard Sorabji and David Bostock, have found Aristotle's reasoning unconvincing, resting either on a fallacy or begging the question.[10] Further, several commentators, including Sarah Waterlow Broadie and Jacob Rosen, have argued that Aristotle's claims here do not fit well with his own discussions of motion and continuity in books V and VI of the *Physics*.[11]

In this paper, I defend Aristotle's reasoning by using his discussion of what to say about the mobile at boundary instants, transitions between change and rest. I show that Aristotle articulates what I call the **Changes are Open, Rests are Closed Rule**: what is true of something at a boundary instant is what is true of it over the time of its rest. By contrast, predications true of something over its period of change are not true of the thing at either of the boundary instants of that change.[12] I argue that this rule issues from Aristotle's general understanding of change, as laid out in *Phys* III 1-3. I then show that it in fact fits well with *Phys* VI, where Aristotle maintains that there is a first boundary instant included in the time of rest, but not a "first in which the mobile began to change." To clarify the rule and its interpretation, I consider how Aristotle uses the **Changes are Open, Rests are Closed Rule** to argue against the possibility of continuous alteration.

I then show how this rule underlies Aristotle's argument that a continuous motion cannot be composed of actual sub-motions. Aristotle distinguishes potential middles,

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[10] Sorabji (*Time*, 323-4); Bostock, 120. White 1992, 54-62; and D. W. Graham (trans. and comm.), *Aristotle:* Physics *Book VIII* [*Physics* VIII] (Oxford: 1999), 141-3; 150-1 are not convinced by Aristotle's reasoning but work harder to find a plausible construal. John Bowin has recently argued that Aristotle's arguments are dialectical, using questionable premises to bring out the problems with Zeno's arbitrary divisions of change (John Bowin, Aristotle on the Unity of Change: Five *Reductio* Arguments in *Physics* viii 8, *Ancient Philosophy* 30 (2010): 319-345). My interpretation makes such a move unnecessary.

[11] Sarah Broadie (Sarah Waterlow (Broadie), *Nature, Change, and Agency in Aristotle's Physics* [*Nature*], (Oxford: 1982), 144-146; Jacob Rosen, "Physics V–VI versus VIII: Unity of Change and Disunity in the Physics," in Mariska Leunissen (ed.), *Aristotle's Physics, a Critical Guide*, Cambridge University Press, 2015.

[12] The adjective "closed," comes from the mathematical distinction between whether a boundary is included in an interval (in which case the interval is open with respect to that boundary) or not (in which case the interval is closed with respect to that boundary). I discuss this in detail in section E.

points passed through en route to a terminus, from actual middles, points that serve as actual termini. The **Changes are Open, Rests are Closed Rule** only applies to actual middles, because only they are boundaries of change, since each is, by definition, the terminus ad quem of one motion and the terminus a quo of the subsequent motion. The mobile must arrive at and then depart from an actual middle.

On my reading, Aristotle argues that the instant of arrival, the first instant at which the mobile has come to be at the actual middle, cannot belong to the time of the subsequent motion. If it did, the mobile would already be moving towards the next terminus and thus, per Aristotle's argument in *Phys.* VI 6, would have already left. But it cannot have moved away from the midpoint at the very same moment it has arrived there. This means that the instant of arrival must be separated from the time of departure by an interval of rest. I show how Aristotle's reasoning applies generally to rule out any continuous reflexive motion or continuous complex rectilinear motion. On my interpretation, however, the argument does not apply to every change of direction. When, as in the case of projectile motion, multiple movers and their relative powers explain why the mobile changes directions, distinct sub-motions are not involved. The mobile need not have arrived at and then departed from any specific point, so the interval of rest argument does not apply. Aristotle needs other grounds for showing that such motions are not continuous. On my reading, Aristotle holds that such motions cannot be continuous precisely because these sorts of cases involve multiple causes of motion, contrary to his definition of continuous motion.

My interpretation of the **Changes are Open, Rests are Closed Rule** allows us to make good sense of Aristotle's argument for thinking that the mobile must stop at an actual middle. Aristotle is correct about the implications of his views on change: his rule implies that there cannot be successive actual sub-motions without intervals of rest. Given that most interpreters take Aristotle's position to beg the question or rest on a premise that is obviously mistaken, this is meaningful interpretative progress. By providing an account of Aristotle's reasoning based on a rule that follows from his general account of change and also has some intrinsic plausibility, I show that Aristotle's position is more defensible and plausible than commentators currently acknowledge, even if the rule on which he relies can be challenged.

C. Aristotle on Why Actual Division Requires Stopping

Aristotle's claim—that a continuous motion cannot be composed of actual sub-motions—is not an obvious one. Nothing appears immediately problematic about taking Socrates' motion from the Piraeus to Athens to be composed of his motion from the Piraeus to a midpoint and his motion from the midpoint to Athens. This is precisely how Zeno's dichotomy paradox gets some purchase on us. Further, Aristotle himself in *Phys* V and VI seems at several points to speak of motions as having parts that are themselves motions, as Sarah Waterlow Broadie and Jacob Rosen point out.[13] What, then, entitles Aristotle to his strong claim?

Earlier in *Phys* VIII 8, Aristotle distinguishes between division in capacity and actual division in order to show that motion in a straight line back and forth between two limits cannot be continuous. Aristotle notes, following his definition in book V, that a motion, if it is to be one and continuous, must be "the motion of one thing and in one time and in what is undivided according to species." (VIII 8, 262a2-3; cf. V 4, 228b2-4)

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[13] Relevant passages include *Phys.* VI 1, 232a8; VI 2, 232b7–8, a34–b2; VI 4, 235a18-24; VI 6, 236b34–237a3; VI 7, 237b23–4. Waterlow, 144-146; Rosen, 214-218. Section D discusses how *Phys.* VIII 8 fits with *Phys.* VI.

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Aristotle thinks that the most evident argument against the continuity of such a motion is that it will not be one in time (VIII 8, 262a13-a18).[14] He claims that a mobile moving back and forth between limits must come to a stand before it doubles back and thus its movements will not be continuous.[15] Any rectilinear motion that requires changing directions at some point will fail to be unified and continuous (VIII 8, 262a1-18).

This argument, crucial to establishing eternal circular motion and to Aristotle's rejection of Zeno, has generally been found unimpressive. I will show that it rewards closer examination. Aristotle lays out two principles for his argument:

> there being three things, the beginning, the middle, and the end, the middle is both in relation to each, and is one in number, but two in account. Moreover, what is in capacity (τὸ δυνάμει) and what is in actuality (τὸ ἐνεργείᾳ) are different. (*Phys.* VIII 8, 262a19-23)

Aristotle first applies these principles to a mobile moving along a straight line:

> Any of the points lying between the limits of the straight line is a middle in capacity (δυνάμει), but not in actuality (ἐνεργείᾳ), unless the mobile divides the line by stopping at that point and beginning its motion again. Thus, however, the middle does come to be a beginning and an end, a beginning of the later part, and end of the first part. (*Phys.* VIII 8, 262a23-27)

Here Aristotle gives an example of the difference between being a middle in capacity and being a middle in actuality. Let us take B, one of the points lying between A and C, the limits of the straight line. If the mobile just passes through B en route, then B is a

[14] Aristotle initially argues that motion back and forth on a straight line (or any reflexive motion) will not be one and continuous because it will involve two contrary, and therefore different, species of motion (VIII 8, 262a6-a13), but he represents the argument based on time as the most evident and conclusive.

[15] It is important to note that this claim, if successfully defended, would also show that such a motion cannot consist of contiguous parts with a single instant serving as the end of one and the beginning of the other. Aristotle had, in *Physics* V, allowed for motions to be contiguous or successive by the limits of their times being one and continuous (V 4, 228a27-b1). If, however, reflexive motions (and other series of motions which require arriving at and then leaving a point) involve rest between each phase, they could not even be called contiguous and thus, since they do not touch one another and lack a common time, there would be no way to compose one motion from a number of these motions.

potential middle. It *is* a middle in capacity because the mobile passed through B and could have stopped there. It is not a fully actual middle because B was not actually the end or beginning of a motion; the mobile did not arrive at and depart from B, it just passed through. If, however, the mobile completes a motion to B and then begins another motion away from B, B will be an actual middle. It will be the terminus ad quem of the motion from A to B and the terminus a quo of the motion from B to C; one in number, but two in account, as Aristotle said.

Can B (or any midpoint) serve as a terminus and be an actual middle without any pause between the two motion? For example, can the post (καμπτήρ) marking the half-way point of the Δίαυλος race serve as the end of the runner's motion to it and the beginning of his motion away from it without requiring any intervening rest at the post? This might initially seem plausible.

Aristotle disagrees. He uses the claim that the mobile must arrive at and then depart from an actual middle to argue that an interval of rest is always required:

> Whenever it is borne continuously, A cannot have come to be at (γεγονέναι) or have come to be away from (ἀπογεγονέναι) point B; it can only be [there] in the now (ἐν τῷ νῦν), not in any time except in the whole of which the now is a division. If some will posit that it has arrived at and has departed from [B], A, while being borne, will always stand. For it is impossible that A has come to be at B and has come to be away from [it] at the same time. So [it will have done so] at different points in time. Therefore what is in the middle will be time. Hence A will rest at B. Likewise in the case of the other points, for the same account applies to all. Thus whenever what is borne, A, uses the middle, B, both as an end and as a beginning, it is necessary that it stop, because of making [B] two, just as if it were understood [to be two]. But it has departed from point A as a beginning, and when it has finished and comes to a stop, it has arrived at C. (VIII 8, 262a28-262b8, OCT text)

To give a concrete example, Moschato, a point in between the Piraeus and Athens, will only be the midpoint of Socrates' journey *actually* or *actively* if it is the end of the motion from the Piraeus to Moschato and the beginning of the motion from Moschato to Athens.

It will only be the end of one motion and the beginning of the other if Socrates both completes his motion from the Piraeus to Moschato and then starts another motion from Moschato to Athens. But Socrates cannot complete his motion to Moschato and start his next motion at the same time, so he must pause. Thus, if Moschato is a midpoint in actuality, Socrates' motion cannot be continuous, since it involves an interval of rest. Any motion that requires arriving at and then departing from a point cannot be continuous.

D. The "Fallacious Instant of Departure" Interpretation

Aristotle claims that the mobile must both have come to be at (γέγονε) the actual middle and have come to be away from (ἀπογέγονε) it.[16] He then claims that there must be an interval of rest in between the mobile's arrival and its departure. Interpreters do not have a problem with the first instant, the instant of arrival. Call this instant t_1. In *Phys* VI 5, Aristotle holds that there is a "first in which the change has finished" (236a8-9), and argues that this must be an initial indivisible moment at which the relevant movement (from A to B in this case) has been completed. (235b33-a13) T_1 is thus the first instant at which the mobile is at B; it is the instant at which the mobile has arrived at or come to be at B. At each instant before t_1 the mobile is still moving and is not yet at B. T_1 is the first instant of having moved, before which there was continuous moving to B.

The problem arises with Aristotle's claim that the mobile must have come to be away from the actual middle. A number of commentators, including Richard Sorabji and David Bostock, claim that Aristotle commits an obvious fallacy here. He assumes that

[16] Both Daniel W. Graham and White note that this is the central premise (Graham 1999, 139; White 1992, 54-55). Though initially inclined to take a reading similar to those of Sorabji and Bostock, White pursues the matter further and comes to a conclusion similar to mine, though, as he notes, does not manage to construe this argument as an 'ordinary language' one (White 1992, 54-58).

there is an instant of departure when there is not. This becomes clear when we lay out the following reconstruction of the argument's premises:[17]

There is some time, call it t_1, when Socrates has arrived at Moschato.

1) Socrates is at Moschato at t_1. (ex hypothesi)

There is some time, call it t_2, when Socrates has left Moschato.

2) Socrates is not at Moschato at t_2. (ex hypothesi)
3) Socrates cannot be at and not at Moschato at the same time. (by definition)

Therefore,

4) t_1 is not the same time as t_2. (from 1-3)
5) Every time is separated from every other time by an interval of time. (by definition)

Therefore,

6) There is an interval of time between t_1 and t_2. (from 4 and 5)

During the interval between Socrates' arrival at Moschato and his leaving Moschato, he must rest at Moschato. Therefore,

7) Socrates is at rest for the interval from t_1 to t_2.

Therefore,

8) The motion of Socrates from the Piraeus to Athens is not continuous.

The obvious mistake is taken to be 2), the assumption of t_2, some particular time when Socrates has left Moschato. On the reading of Bostock and Sorabji, Aristotle assumes

[17] This construal of the argument and objection is seen in both Richard Sorabji (*Time*, 324) and David Bostock, 'Aristotle, Zeno, and the Potential Infinite', in *Space, Time, Matter, and Form: Essays on Aristotle's* Physics, (Oxford: 2006), 120.

that there is some first point of time at which Socrates has left Moschato. This assumption is false.

There is no first instant of change. There is no instant of departure at which the mobile has come to be away from the midpoint. Instead, a continuous range of times follows the instant at which the mobile is at the midpoint and at all of these instants the mobile is no longer there. Either Socrates is still at Moschato, in which case he has not departed from it, or he is some distance away from it, in which case he has already departed, meaning that the instant in question cannot be the first instant of departure. We can take instants of time that are very close to Socrates' departure, but there is no first instant there for us to pick out.

This interpretation is, however, prima facie problematic because Aristotle seems to be well aware that there is not a first instant of having changed. Aristotle earlier argues at length that there cannot be such a thing (VI 6, 236b33-237b9, considered below in section D), an interpretative difficulty Richard Sorabji addresses only by asserting that Aristotle lacked a "firm grasp" of the continuity of change.[18] In fact, we can make good sense of Aristotle's reasoning. I will show that instead of burdening him with a commitment he explicitly rejects elsewhere, we can use Aristotle's *Phys* VI views on changing and having changed to formulate a cogent and powerful interpretation of this passage. To do so, however, we need to better understand why Aristotle claims that the mobile must have come to be away from (ἀπογέγονε) the midpoint.

[18] Richard Sorabji, 'Aristotle on the Instant of Change', *Proceedings of the Aristotelian Society,* supplementary vol. 50 (1976), 85.

E. Aristotle on Predications at Boundary Instants

To reach this understanding, we need to look at a passage later in the chapter where Aristotle discusses what is true about a mobile at boundary instants, using the case of alteration:

> It is also clear that unless one makes the point of time dividing the earlier and later always be, with respect to the thing, of what is later (τοῦ ὑστέρου τῷ πράγματι), the same thing will be and not be at the same time, and when it has come to be, it will not be. The point, then, is common to both (to the earlier and to the later [time]), and is the same and one in number; in account, however, it is not the same (for it is the end of the one, but the beginning of the other). In the thing, however, it is always of the later condition (τοῦ ὑστέρου πάθους). Let the time in which be ACB, the object, D. This in time A is white and in time B is not white. So in C it is white and not white. For in any [instant] whatever (ἐν ὁτῳοῦν) of A it is true to say it is white, if it was white for this whole time, and in B not white, but C is in both. Thus one must not grant [that it is white] in every [now], but instead [in every now] except for the final now, C. This is already in the later time. And even if it was coming to be not white and white was perishing in the whole A, it *has* come to be or *has* perished (γέγονεν ἢ ἔφθαρται) in C. Hence, it is first true to say that it is white or not white in that instant. Otherwise, when it has come to be, it will not be and when it has perished, it will be; or it must be white and not-white at the same time and, generally, being and non-being. (*Phys.* VIII 8, 263b9-26)

In this passage, Aristotle is making a general claim about the boundary instant separating a time in which the subject possessed one status (but was moving towards having a different status) from the time in which it has gotten its new status. The instant C is the boundary for two times: the earlier time AC, over which thing D was white, and the later time CB, over which thing D was not white. In general, Aristotle insists that if something has a certain status over a whole time, that status also applies to all the instants within that time. If thing D was white over the time AC, then it was white at any instant within that time. But this brings up a potential problem. If the instant C belongs to both of the whole times, AC and CB, in the same way, then both the predications that are true over AC and those that are true over CB will apply. Thing D is white over time

AC, so it is white at C. Thing D is not-white over time CB, so it is not-white at C. Thus at instant C, thing D is white and not-white: contradictory predicates would be true of the same thing at the same time.

To avoid this, Aristotle says that the boundary instant should always be taken to belong to the later time, not the earlier one. W.D. Ross is not impressed with this move:

> To avoid the difficulty involved in admitting that at one moment a thing may both be and not be possessed of a certain quality, Aristotle here states the equally difficult view that while a moment belongs both to the time which ends at it and to that which begins at it, it 'belongs to the later, i.e. to the later qualification, for the thing.[19] (Ross 1936, 714)

Ross is dubious about whether Aristotle's position is at all plausible or merely an ad hoc invention. I will consider how we should interpret it, show that it issues from Aristotle's earlier views on motion, and then lay out how it applies.

To begin with, how should we interpret Aristotle's claim? In my view, we can best articulate Aristotle's view by employing the mathematical notions of closed and open intervals. These notions apply well to Aristotle's understanding of continuous quantities on which they are conceptualized quasi-geometrically. A continuous quantity is closed if its limit points are included within the quantity and open if its limit points are not included.[20] On my view, when Aristotle claims that "one must not grant [that it is white] in every [now], but instead [in every now] except for the final now, C." we should read him as claiming that the time AC is open. It contains all the instants up to, but not including, its final limit, the instant C. This fits well with his next claim, that "[C] is already in the later time." The succeeding time CB includes the instant C, so CB is closed at that limit.

[19] Cf. Graham 1999, "Whereas a modern interpreter might look at this move as a mere stipulation to avoid problems, Aristotle sees it as required by the facts themselves." (144)

[20] Weisstein, "Closed Interval," "Open Interval." It is half-open if one of its limit points is not included within the interval, but the other is.

This interpretation allows instant C to function as the limit for both times while properly being included in only one, avoiding contradictory predications.[21] The distinction between open and closed intervals is widely recognized as an important and valuable one, so there is no problem with the concept itself.

The question, however, is why Aristotle insists that it is the latter time that is closed and the earlier one that is open. In fact, this claim is not arbitrary but follows from Aristotle's views on motion, as expressed earlier in the *Physics*. Aristotle sees motion as a distinctive way of being, incomplete and in process. Aristotle describes motion as the "fulfillment (ἐντελέχεια) of the potential, as such." (III 1, 201a11-12) During a motion, something's potential is being made actual, but as long as the motion is ongoing this fulfillment is not yet complete. Aristotle illustrates with the example of building:

> For each thing is sometimes active (ἐνεργεῖν) and sometimes not. Take, for example, the buildable (οἰκοδομητόν). The activity (ἐνέργεια) of the buildable, as buildable, is building (οἰκοδόμησις). For its activity is either building or the house, but when the house is, the buildable no longer is. It is the buildable, however, which is being built. It is necessary, therefore, for building to be its activity. But building is, indeed, a certain motion (κίνησίς) and the same account will apply to the other motions. (201b7-15)

Aristotle is pointing out two things. First, the buildable is only being fulfilled or made actual when it is being employed in building. Bricks and mortar can be built with (they are

[21] Aristotle's account of location offers further support for the importance he attaches on making distinctions even when the limit is one in number and for applying the closed/open distinction. In *Physics* III 4, Aristotle maintains that "the place is together with the thing. For the limits are together with the limited." (212a30-31) The container and the thing contained share the same boundary: for example, the inside of the amphora touches and has the same limit as the wine it contains. This boundary, just as in the case of the now, is one in number, but two in account (the end of the wine and the beginning of the amphora). There is still a real difference for Aristotle. Indeed, he characterizes place as "the first immobile limit of the containing." (a21-22) The place of something is given and defined by what does the limiting, not by what is being limited. The amphora, its shape and boundaries, give a location to the wine it contains. Thus the limit is a limit for both the thing contained and the container, but belongs primarily to the container. The contained thing is open with respect to its boundaries.

building materials even when not being used), but they only become actually buildable things when employed in constructing a house. Secondly, when the bricks and mortar have become a house, they are no longer buildable. When they are components of an actual built thing, they no longer have the potential to be used as the material for building (as long as the house persists). The completion of building is the end of the buildable as such. So, for Aristotle, the end and limit of the motion is outside of the motion itself and involves the thing having a fundamentally different status than it did while the motion was ongoing.[22]

In *Phys.* VI, Aristotle works out the implications of these facts about motion for the times of motions. Here he makes claims about both the beginnings and ends of motions. First, he notes that, "there is no first [part] either of what is changing or of the time in which it changes." (VI 5, 236a36-7) Aristotle is claiming that there is no first instant at which something is changing. Insofar as something is moving it has already moved. If an apple is becoming red, it has already become partly red. If it were still entirely green without having ripened at all, it would not be true to say that it is becoming green, as its potentiality to become red would not be actualized at all. Thus the apple will already have come to be red (to some degree) at any instant of its ripening.[23]

As we will see, this means that the initial boundary of a change is also not included in the whole time of the motion. Instead, it belongs to the preceding time of rest. If instant G separates the earlier time of rest, FG, from the subsequent time of motion,

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[22] For further discussion of this passage see Graham 1988, Kosman 1969, Waterlow 1982.

[23] Similarly, there is not a first part of the change in the thing undergoing the change. Whether we take some initial redness of the apple, or movement of the animal, or growth of the plant, there will always have been some earlier alteration or locomotion or growth, some preceding change in the thing. (VI 5, 236a13-37)

GH, G itself will belong to the time of rest and the mobile's status at G will be determined by time FG. My view here is in line with Michael White's interpretation of the instant of departure. In his discussion of Aristotle's views on the beginning and end of motion, White presents and argues for understanding the instant of departure as the last instant of resting. It is the last instant of having not moved, after which there will be moving. Although Aristotle does not explicate this notion, it is the analogue of the instant of departure, to which Aristotle is explicitly committed, and it follows naturally from his denial of a first instant of change. It is similarly defined in terms of something stative, not something in motion.[24]

Aristotle's denial of a first instant of changing leads him to the further claim that, "everything which is moving has moved before." (VI 6, 236b33-34). If we take any instant within Socrates' motion from the Piraeus to Moschato, Socrates will have already moved away from the Piraeus. No matter how early in Socrates' motion we are, there will always be some previous interval of time during which he has already moved away from the Piraeus (236b34-237a30). If something is now moving, it has moved. This is the view that Sorabji and Bostock claim Aristotle is contradicting in *Phys* VIII. In fact, I will show that he is using this view—that if something is moving, it must have moved—to show that continuous motions cannot be composed of actual sub-motions.

Aristotle's views on what to say about the end of change in *Phys* VI also fit well with my interpretation of *Phys* VIII on boundary instants. He insists that there is, indeed, a "first in which the change has finished" (236a8-9), a first instant when the motion is over and the change is complete. With respect to D, the thing being altered, "it is first

[24] White 1992, 57.

true to say that it is white or not white in that now [i.e. C].” (263b23-4) If, as in the VIII 8 example, D is white over time AC and then not-white over time CB, the now or instant C is the first point at which it can be said to have come to be not white and at which it can be said that the white in it has been destroyed. It is the “first in which the change has finished.” More generally, Aristotle is claiming that there is a first instant when the change has been completed and is no longer taking place.

On my interpretation, Aristotle’s view of motion implies the claims he makes in *Phys* VIII. The boundary instant, as the first instant when the change has been completed, must belong to the subsequent period. Thus the predications that applied to the mobile during its previous motion no longer apply. More generally, we have seen that Aristotle insists that there is no first instant of motion and no last instant. This means that the times of motions are open (they do not include their end limits). On my interpretation, Aristotle’s metaphysics of change implies a **Changes are Open, Rests are Closed Rule**:

> *What is true of something at a boundary instant is what is true of it over the time of its rest, whether that time of rest precedes or is subsequent to the time of the change; predications true of something over its period of change are not true of the thing at either of the boundary instants.*

Times of change or motion are always open: they do not include either a first instant or last instant of change. Times of rest, by contrast, include their boundaries. There is a first instant of rest or completion and a last instant of resting, after which there is motion.

F. Rest at an Instant and Predications at Instants

My interpretation might seem to be in tension with some of the views on time and rest that Aristotle expresses in VI 8. There he claims that just as there is no first in which something moves or comes to a stop, so “neither is there a first when the resting thing rested.” (οὐδὲ δὴ τὸ ἠρεμοῦν ὅτε πρῶτον ἠρέμησεν ἔστιν) (239a12) Aristotle goes on to argue against both a first instant of rest and a first interval of rest. He argues that just as there can be no moving in what is indivisible, so there can be no resting in what is indivisible. Thus an instant is not the sort of thing that could be a candidate for when the first rest happens. (239a12-14) On the other hand, there can be no first interval of rest, because the supposed first interval could always be divided into parts, one of which would be prior. (239a14-19) Aristotle maintains that the lack of a first follows from the continuous character of the entities involved:

> The cause of this is that everything rests and is moving in time, and there is not a first time, nor a first magnitude, nor, in general any first continuous [thing]; for these are all infinitely divisible.[25] (239a20-23)

He later says that “neither moving nor resting are in the now” (239b2-3) (οὔτε γὰρ κινεῖσθαι οὔτ’ ἠρεμεῖν ἔστιν ἐν τῷ νῦν) Does Aristotle’s rejection of a first instant of rest call into question my **Changes are Open, Rests are Closed Rule**?

Aristotle’s remarks show that he denies a first instant of rest in the sense of a first time over which rest is taking place. This, however, is not the sort of instant of completion that my **Changes are Open, Rests are Closed Rule** implies. VI 8 does not give us reason to reject the idea that the boundary instants should be included with the period of rest as opposed to the period of change. After all, it is not only in book VIII that Aristotle associates the boundaries with rest instead of change. As I noted earlier, in VI 5 Aristotle argues that there is a “first in which the change has finished” (τὸ ἐν ᾧ πρώτῳ μεταβέβληκε) (236a8-9), where this first is an instant. I take Aristotle’s

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[25] Τούτου δ’ αἴτιον ὅτι ἠρεμεῖ μὲν καὶ κινεῖται πᾶν ἐν χρόνῳ, χρόνος δ’ οὐκ ἔστι πρ ῶτος οὐδὲ μέγεθος οὐδ’ ὅλως συνεχὲς οὐδέν· ἅπαν γὰρ εἰς ἄπειρα μεριστόν

claim there to imply that the predications that are true of the thing once it has completed the change apply at that instant (and going forward, for as long as it rests in that state). The appropriate predications for the first instant of completion or rest depend on the mobile's status during the period of rest. There is a first instant at which the mobile became pale or got to Athens or completed its growth and that instant is the first at which it is true to say that it is white, is grown, or is in Athens. It is in this sense that there is a first instant of rest or completion. Conversely, his denial in VI 5 that there is a "first in which the mobile began to change" (τὸ ἐν ᾧ πρώτῳ ἤρξατο μεταβάλλειν) implies that there is no instant or temporal interval at which it is first true to claim that the mobile is changing (e.g. becoming white, moving to Athens, or growing).

My interpretation concedes that, strictly speaking, the mobile neither moves nor rests over any instant, since motion or rest require an extended (hence divisible) time. However, the mobile will either be moving or resting over the temporal interval in which an instant is included. This allows for a derivative sense in which the mobile can be said to be in motion or at rest in the instant. The mobile is in this state at the instant insofar as it is in that state over the whole time in which this particular instant is included. Aristotle clearly thinks that predications that are true over the whole time can rightly be applied to the instants included in it. This is precisely how he reasons about boundary instants at 263b19-20: "for in any [instant] whatever (ἐν ὁτῳοῦν) of A it is true to say it is white, if it was white for this whole time [A]." If we pick an instant halfway through Usain Bolt's record-setting 100m sprint, he will not be running in the instant itself. Nevertheless, it is still true to say that he is running at that instant insofar as that instant is included in the larger temporal interval throughout which he is running.

G. Using Boundary Instants against Continuous Alteration

Another example from later on in the chapter provides further evidence for my view that changes do not include their boundary instants. It also shows why this claim is crucial for Aristotle's overall position on the need for intervals of rest between changes. In this passage, Aristotle is presenting an argument against the continuity of reflexive alteration. Aristotle is arguing that it is impossible for something to undergo an alteration (into white, in the example) and then immediately, without any rest, undergo an opposite alteration (out of white and into not-white, in the example).

> for at the same time not-white has been destroyed and white has come to be. If, then, the alteration into white and out of white is continuous and [the mobile] does not remain [white] for some time, at the same time not-white has been destroyed [ἔφθαρται] and white has come to be [γέγονε] and not-white has come to be [γέγονε]. For there will be the same time of the three. (264b3-6)

We can see the role that Aristotle's views on motion and rest play here when we explicate the example. Let the mobile D be becoming white over time AC and then be becoming not-white over time CB. On this scenario, the instant C_0 is the first instant of having completed the change, since it is the endpoint of time AC, the time over which the mobile is altering to white. This means that at instant C_0 the mobile has become white and not-white has been destroyed. As we have seen, since time AC is the time over which mobile D is becoming white, the time at which it is white, instant C_0 must fall outside this time, given Aristotle's views on change. C_0 is the first instant in which the change has finished. This is why Aristotle claims that, at instant C_0, white has come to be and not-white has been destroyed. White coming to be and not-white being destroyed are the actualities of the change, what the change produced, and so these claims are true at the boundary of the change, its outside limiting point.

Now why does Aristotle say that not-white "has come to be" at this very same instant? This, again, goes back to Aristotle's view of motion: "the actuality of the alterable, as alterable, is alteration." (201a12-3) Something is altering insofar as it is actually being altered: something is whitening insofar as it is actually being whitened. As we saw, Aristotle argues in *Phys.* VI 5-6 that insofar as something is moving it has already moved. If an apple is becoming red, it has already become partly red. If it were still entirely green without having ripened at all, it would not be true to say that it is becoming green, as its potentiality to become red would not have been actualized at all. Thus the apple will already have come to be red (to some degree) at any instant of its ripening.

In our example, mobile D is, ex hypothesi, becoming not-white during the whole time CB, without any break or pause from its previous alteration to white. Given that it is becoming white during the whole time CB, at any instant within that time, it will have actualized its potential to some degree and thus will have come to be not-white to some degree. Now since instant C_0 is not part of the previous time, AC, it must be part of this subsequent time, CB. Instant C_0 is part of the whole time and the mobile immediately starts becoming not-white. This means that, at instant C_0, it must already have become not-white to some degree. Thus we get a contradiction. At instant C_0, the mobile has become white and not-white has been destroyed, since it is the terminus of the alteration to white, the first instant at which the mobile has changed. However, because C_0 is, ex hypothesi, part of time CB during which the mobile is becoming not-white, the mobile has also become not-white at C_0.

The way to resolve this contradiction is to deny that the mobile immediately alters to not-white. If there is a period of rest before the mobile starts altering again, a period that includes its limits, then the contradiction disappears. Generally, Aristotle claims that, in any change, the mobile must have arrived at the terminus and rested there before undergoing any other motion. This is true whether we are talking about alteration, growth and diminution, generation and corruption, or change of place.

Now, one might object that there is another way to avoid the contradiction that does not require such a definite rule: we can just not include instant C_0 with either time AC or time CB. If it is part of neither time, then no problems arise, as there is no need to apply contradictory predicates to the mobile at C_0. But this means that we do not know what to predicate about the mobile at instant C_0 (e.g. is it white or not-white? has it come to be white?), nor are we in a position to affirm that the initial alteration to white has actually been completed, since we do not have grounds for claiming that at instant C_0 the change has actually been completed. Even more seriously, for Aristotle, an instant that does not measure either motion or rest cannot be its own independent time, or, in fact, be at all. Aristotle defines time as "the number of motion according to before and after." (*Phys*. IV 11, 220a25-6) Time exists as a measure of motion and, incidentally, of rest (*Phys* IV 12, 221b7-23): it has no independent existence. Different times measure different motions or rests. Time is not composed of instants, rather we can take instants or nows because there is a whole motion or rest that they measure. If there is no change or motion or no whole time to measure, there could not be an independently existing instant of time. Thus for Aristotle every instant needs to be part of some continuous whole time.[26]

[26] For a comprehensive discussion of Aristotle's views on time see Coope 2005.

H. Aristotle's Reasoning Applied to the Actual Midpoints of Local Motion

Now, how does the **Changes are Open, Rests are Closed Rule** apply to local motion? Why, precisely, does Aristotle claims the mobile must rest at an actual middle, a place that the mobile has come to be at (γέγονε) and then has come to be away from (ἀπογέγονε)? Aristotle's use of the perfect tense here is significant, since much of the force of his reasoning comes from the completed aspect denoted by γεγονέναι, "to have come to be at" or "to have arrived at" and ἀπογεγονέναι, "to have come to be away from" or "to have departed from," as Daniel Graham rightly points out.[27] Both Graham and White argue that Aristotle uses the perfect to signify a continuing state or achievement that is the result and goal of some prior activity or motion. The perfect stresses "an actual continuing state," as Graham puts it, one that is achieved through the completion of a process.[28] As White notes, the process leading to the goal needs to be finished "in a 'semantic' as opposed to a merely temporal sense."[29] It is only appropriate to apply the perfect to the coming to be of something when that thing is in a completed state of being as a result of a successfully completed process. In the case of motion, one motion must have been completed and then the other must have begun. This allows Aristotle to run the same kind of argument we saw in his rejection of reflexive alteration. On my interpretation, instead of fallaciously assuming a first instant of change, we should read Aristotle as implicitly relying on the *Phys* VI claim that whatever is changing has changed to argue for distinct times separated by rest.

[27] Graham 1999, 139. Graham does, however, run into the same interpretative difficulty as Sorabji and Bostock when he analyzes Aristotle's argument (VIII 8, 262b23-262a3) that a reflexive motion cannot be continuous (Ibid., 141-143).

[28] Graham 1980, 125.

[29] White 1980, 255 Cf. Lyons 1972, 113.

Why Continuous Motions Cannot Be Composed of Sub-motions

So, how does the argument work on my reading? The mobile *has arrived* at B, precisely because B is the actual terminus of its initial motion.[30] The mobile must have completed a motion to B. This is what distinguishes arriving at or coming to be at B from passing through B as a potential part of a larger motion that is not yet fully actualized. This is also what ensures that the **Changes are Open, Rests are Closed Rule** applies. Both when B is a potential middle and when it is an actual middle, the mobile will be at B at some instant. However, when the mobile is just passing through, it is moving to some different destination and so that instant is not an actual boundary or limit that serves as a terminus and fulfills the mobile's capacity.

Given, however, that B is an actual middle, the mobile must be at B and must have moved to B at t_1, the instant of arrival. The **Changes are Open, Rests are Closed Rule** implies that t_1 cannot be part of the time over which the mobile was moving to B. Instead, it must go with the subsequent time. The mobile has at t_1 whatever status it will have over the whole subsequent time BC. Ex hypothesi, however, its motion is continuous. We are assuming that there is another motion from B to C that occurs right after the time of the mobile's motion to B without any intervening pause. In our example, Socrates will go right from moving to Moschato into moving to Athens, without any

[30] Aristotle's understanding of the implications of γέγονε, "having arrived at" and ἀπογέγονε "having departed from" fit with ancient Greek usage and with ordinary English uses of perfect predications. If you are taking the train from the Piraeus to Athens and the train stops in Moschato, you certainly might say that, "We've arrived in Moschato." Once the train starts up you might say "We've departed from Moschato." If you are on an express train which passes through Moschato but does not stop there, you would probably not speak of arriving at or departing from Moschato. When the train is passing through the Moschato station you might say, "We're in Moschato right now," or "We're just passing through Moschato," but you would avoid speaking of arriving at and departing from. Similarly, if you take the express train and someone later asks you whether you have been to Moschato: you would probably say that you have passed through it. You would not unqualifiedly say that you have been there, however, because you never stopped or rested there. It has never been your destination or even a stopping point. Aristotle's understanding of motion and continuity, then, fits well with how we speak and understand things.

pause. This, however, means time BC, the time of the subsequent motion is the only time that can include t_1. Thus the instant of arrival would also turn out to be part of Socrates' motion from Moschato to Athens.

This implies that Socrates is moving to Athens at t_1. But, if this is true, then we know from *Phys*. VI that Socrates has moved away from Moschato and towards Athens at t_1. This is true of all instants that are part of the time of Socrates' motion from Moschato to Athens, so it must be true of t_1. This, again, produces a contradiction. At t_1 the mobile has arrived at B and is at B, since t_1 is the first instant at which it has completed its motion to B. However, at t_1 it has moved away from Moschato, since, ex hypothesi, it is moving from Moschato towards Athens at t_1. These predications cannot be true at the same time—something cannot have arrived at a place and be moving away from it at the same instant.

Applying the **Changes are Open, Rests are Closed Rule** thus allows us to make good sense of the text of Aristotle's argument for thinking that the mobile must stop at an actual middle:

> For it is impossible that A has arrived at B and has departed from [it] at the same time. So [it will have done so] at different points in time. Therefore what is in the middle will be time. Hence A will rest at B. (262b1-4)

Arriving at B and then departing from B requires rest. If B is an actual midpoint, the mobile must pause there. We now have a reconstruction of the argument that is based on *Phys.* VI instead of conflicting with it, avoiding the worry about inconsistency put forward by Broadie and Rosen. This interpretation also leaves us with an argument based on defensible premises, not on an obvious mistake, à la Bostock and Sorabji.

We can now formally lay out the premises and conclusion. Let us assume that Moschato is an actual midpoint of Socrates' motion. Therefore, there is some instant of time when Socrates has arrived at Moschato and completed his motion to it. We will call this instant of arrival, t_1.

1) T_1 is the first instant at which Socrates is at Moschato (ex hypothesi)

Let AB be the time of motion from the Piraeus to Moschato, of which t_1 is the closed endpoint. The **Changes are Open, Rests are Closed Rule** then implies

2) T_1 is not included in the whole time AB, the interval of time over which Socrates is moving from the Piraeus to Moschato (from the **Changes are Open, Rests are Closed Rule**)

But t_1 must be part of some larger interval of time, as Aristotle clearly assumes in 263b9-25, when he is determining the mobile's status at a boundary instant. Aristotle is assuming throughout VIII 8 that every instant must be part of some larger interval of time. As I discussed at the end of section G, this fits with Aristotle's understanding of time as a measure of motion. Just as every instantaneous position is grounded in the larger motion or rest it is part of, so any instant of time is grounded in the larger time interval that includes it. Thus t_1 must go with the subsequent time.

3) T_1 must be included in the subsequent temporal interval (from 2 and the fact that the only other temporal interval it could be in is the subsequent one)

Now let BC be the time of Socrates' motion from Moschato to Athens. On the assumption that Socrates goes simultaneously from one actual motion to another, Socrates is moving from Moschato to Athens in the immediately successive temporal interval, so that time would immediately follow time AB.

4) The subsequent temporal interval is temporal interval BC, over which Socrates is continuously moving from Moschato to Athens (ex hypothesi)

Note that the temporal interval BC does not include the instant of arrival at Athens, since, per the **Changes are Open, Rests are Closed Rule**, this instant goes with the subsequent time and is one at which Socrates is no longer moving to Athens. These two premises then imply that:

5) T_1 is included in temporal interval BC (from 3 and 4)

We can now draw out the implications that follow from t_1 belonging to an interval of time in which Socrates is continuously moving from Moschato to Athens:

6) Whenever Socrates is moving from Moschato to Athens, Socrates has moved away from Moschato and towards Athens (from VI 6, 236b33-34, on moving and having moved)
7) Socrates has moved away from Moschato and towards Athens at t_1 (from 4, 5, and 6)
8) At t_1, Socrates is at Moschato and not at Moschato (from 1 and 7)
9) Socrates cannot be at and not be at Moschato at the same time (by definition)

Therefore,

10) 4) is false: BC is not the temporal interval that succeeds time AB and includes t_1 (from 8 and 9)

T_1 is not part of time BC and BC is not the temporal interval that succeeds time AB. But this means that t_1 must be part of some other temporal interval that comes before BC, a temporal interval that will have to be an interval of rest. To further see this note that the **Changes are Open, Rests are Closed Rule** implies that there must be an initial limit to Socrates' motion from Moschato to Athens that is outside of it. Following White, we can call this the instant of departure to Athens. Let t_2 be the instant of departure after which Socrates has left Moschato, but at which he is still at Moschato. Then,

11) T_2 is the last instant at which Socrates is at Moschato (ex hypothesi)

But this implies that

12) The whole time BC, the interval of time over which Socrates is moving from Moschato to Athens, is the time that succeeds t_2 (from 11 and definition of instant of departure)

But we just saw that BC is not the time that succeeds t_1. Since they are succeeded by different temporal intervals, t_1 and t_2 cannot be the same. Instants are individuated by the times they bound, so instants that bound a different time cannot be the same. Thus

13) T_1 and t_2 are not the same instant (from 10 and 12 and because different temporal intervals succeed them)

But,

14) Every time is separated from every other time by an interval of time. (by definition)

Therefore,

15) There is an interval of rest between t_1, the instant of arrival, and t_2, the instant of departure. (from 13 and 14)

During the interval between the instant of Socrates' arrival at Moschato and the instant of departure, t_2, the instant after which he has left Moschato, he must rest at Moschato. Therefore,

16) Socrates is at rest for the interval from t_1 to t_2.

Therefore,

17) The motion of Socrates from the Piraeus to Athens is not continuous.

I. Reflexive and Complex Rectilinear Motions

At this point, the advocate of Zeno might present a revised objection by turning to reflexive motions or rectilinear motions in a series of distinct directions. Perhaps when the mobile is moving directly from A to C it would have to stop for an intermediate point on its route to be an actual midpoint. But consider cases where, after moving forward to B, the mobile then moves down to D or back to A. In these instances, B clearly serves as an actual terminus: the mobile's intermediate goal is to get to B and once it arrives there it then moves in a different way, either back to A or down to D. In such cases, what prevents the instant of arrival from also being the instant at which the mobile starts its next motion, either back to A or down to D? Here, again, Aristotle can employ his rule to show that these complex rectilinear or reflexive motions must involve intervals of rest and thus cannot be continuous.[31]

Consider a case where the mobile arrives at B and then moves downward to D. T_3, the instant of arrival, is the first instant of having changed. At t_3 the mobile is at B and has arrived at B. But, again, the **Changes are Open, Rests are Closed Rule** means that t_3 goes with the subsequent time. If during this whole subsequent time the mobile is moving to D, then at t_3 it will have already moved away from B and towards D. But the mobile cannot have arrived at B and have moved away from B at the same instant. So again we have two distinct instants that must be separated by an interval of rest. Similar reasoning applies to the case of reflexive motion: the mobile cannot have arrived at B while simultaneously having moved back towards A and away from B. Thus even in

[31] Aristotle gives additional arguments for claiming complex rectilinear or reflexive motions cannot be continuous, but insists that the fact that motions requiring actual middles involve an interval of rest makes "most apparent," (μάλιστα φανερόν), (262a12) the impossibility of such motions being continuous.

cases where the mobile changes directions at the actual middle, there must be an interval of rest, destroying the motion's continuity.

Aristotle goes on to use this result as the basis for a general rule that shows that only circular motion can be continuous:

> For circular motion is from the same to the same, but rectilinear motion is from the same to the other. And motion in a circle is never over the same [points], but rectilinear motion is repeatedly over the same [points]. It is possible for a thing that comes to be always in different points to move continuously; but it is not possible for a thing that comes to be repeatedly in the same points. (264b18-b28)

Here Aristotle articulates what I will call the no-backtracking rule:

> **No backtracking**: if a motion from starting point A traces part of its course again before returning to the starting point A, that motion cannot be continuous.[32]

This rule comes from Aristotle's arguments for an interval of rest. When the mobile starts backtracking, whether this is by turning around at the end of a rectilinear motion, reversing course on a semicircle (264b24-5), or in some other way, the point of turnaround must be an actual middle. It is the actual end of the motion out and the beginning of the actual motion back. In consequence, the mobile must arrive at and depart from the turnaround point, necessitating an interval of rest (given the **Changes are Open, Rests are Closed Rule**) and destroying the continuity of the motion. **No backtracking** means that any movement of place that involves a retracing of steps will fail to be continuous. It gets Aristotle to the overall target of the chapter: the priority of circular motion.[33]

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[32] As my formulation of this rule makes clear, I agree with Graham in restricting the claim that motion in a circle never covers the same points to the motion of a single revolution (Graham 1999, 153-4).

[33] Aristotle had initially used the argument to rule out infinite rectilinear motion, paving the way for his claim that only circular motion can be infinite and continuous (*Phys.* VIII 8, 262a13-263a4). Since Aristotle assumes that the universe is finite (as he argued at *Phys.* III 5; cf. *Phys.* III

This principle also rules out the possibility of continuous series of alterations or continuous series of generation and corruption because these also involve actual middles. As we saw earlier, the white thing must actually come to be black in such a way that it is not at that same instant partly white again. Thus it must rest in this state for some finite time before turning back to white. Similarly, the dead thing must actually come to be alive and cannot be dead again at the same instant: it must rest in its living state for some finite time before dying again. This is the central ground for Aristotle's rejection of the sort of continuous universal flux associated with Heraclitus and sketched out in the *Theaetetus*.[34] If, as I have argued, Aristotle's argument for rest follows from his rule, then Aristotle can directly apply it to alteration and substantial change to rule out perpetual flux.[35]

J. Motions involving Multiple Movers

I have articulated and defended Aristotle's reasons for thinking that a continuous motion cannot be composed of actual sub-motions. I then argued that this reasoning applies both to reflexive rectilinear motions and rectilinear motions with multiple termini. We now need to consider a different kind of case that commentators raise. Both Graham and Rosen object to Aristotle's reasoning by mentioning the example of violent projectile

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6 207a16-20), any infinite rectilinear motion would require turning around at some point i.e. moving rectilinearly in a different direction.

Note that, as I suggested above, some motions that are not purely circular, such as elliptical motions, will be able to pass the **No Backtracking** test. However, these tests do rule out any motion that consists solely of some combination of rectilinear motions.

[34] Cf. Heraclitus B60; *Theaetetus* 152d-e, 160d and following.

[35] Graham recognizes that Aristotle's rejection of flux seems to be appealing to his previous arguments about resting, but finds Aristotle's reasoning for ruling out continuous cycles unconvincing, because Graham has not made found Aristotle's earlier argument satisfactory (Graham 1999, 156-157).

motion: surely, the apple thrown upwards does not need to pause before coming down.[36] Considering this case helps to clarify Aristotle's reasoning. Does the argument Aristotle gives in *Physics* VIII 8 imply that an apple thrown upwards pause before descending? I will examine the relevant conditions for Aristotle's interval of rest argument by looking at this and several other putative counter-examples that commentators suggest. On my interpretation, Aristotle's reasoning does not apply in these cases because the changes of direction occurring in them do not, in fact, occur as a result of actually distinct sub-motions with their own termini. Instead, the relative powers of the multiple movers explain these changes of direction. Since the mobile need not have arrived at and then departed from any specific point, the interval of rest argument does not apply. In my view, Aristotle's reasons for thinking that such motions cannot be everlasting and continuous rest on the definitional conditions he lays out for a motion to count as continuous, not on his argument for an interval of rest. Even if such motions are not divided in time, Aristotle insists they are not continuous because their movers are not sufficiently unified.

On my reading, the uppermost point of the apple's flight (20 feet, say) is not an actual middle in Aristotle's sense, and thus is not governed by the **Changes are Open, Rests are Closed Rule**. This case is importantly dissimilar from the case of a mobile getting to its intermediate goal and reversing course (like the runner reaching the post marking the halfway point of the race and turning around). The runner's motion consists of two sub-motions: the one to the halfway point and the one back from that point. The runner is only allowed to move back after she has arrived at the intermediate point. By

[36] Graham 1999, 142; Rosen, 206.

contrast, the apple does not perform one motion to a precise point 20 feet up in the air and then initiate a distinct sub-motion back down. Instead, for Aristotle, the ball's motion is the result of two opposed powers, the power of the thrower that propelled it upwards and the ball's heaviness that carries it back to the earth. Aristotle thinks that the combined effect of these two powers determines the ball's trajectory (VII 2, 244a23025). The zenith of the ball's motion does not play any explanatory role in its flight. It is not a terminus ad quem or terminus a quo.

The relative unimportance of the point of maximum height can be brought out by considering a case where the ball is thrown forwards and slightly up e.g. thrown at a five-degree angle. In this case, there will be some point in the course of the motion, call it H, at which the ball reaches its greatest vertical distance from the ground. Does the ball need to arrive at and depart from H, and thus rest at H? On my interpretation, Aristotle's view does not require a pause in such a case because there are not actual sub-motions to and then away from H. H is not a terminus or a goal for which the ball is moving. It is just the point at which the ball happens to reach its greatest height, before the power of its heaviness overcomes the power of its upward propulsion. Since H is not a terminus, the ball need not arrive at or depart from H and the **Changes are Open, Rests are Closed Rule** is not relevant. We cannot rightly apply the Ancient Greek perfect in either of these scenarios, saying that the mobile has come to be at the zenith, because in both scenarios reaching this point is not an achievement that is the result and goal of the mobile's prior motion. Instead, the zenith's status as the highest point is coincidental on the way the relative motive powers interact.

This clarification is relevant to several other suggested counter-examples. Suppose that Socrates is on a moving walkway propelling him forward at a velocity of 5 km/h, when he turns around and starts to walk the other way, continuously accelerating until he is walking at the velocity of 7 km/h. At the end of his acceleration Socrates will be moving at 2 km/h in a direction opposite to his initial course. At some point along this acceleration, Socrates' own velocity will perfectly cancel out the velocity of the moving walkway, but there is no reason to think that he must pause for an interval of rest at this point. The point where the relative velocities cancelled each other out will not be a terminus a quo or ad quem. Since, again, there are no actual sub-motions to or from this point and it is not a continuing state or achievement that completes Socrates' motion, Aristotle's argument does not apply.[37]

Graham presents another case in a similar vein: "contrary motion along a continuous sine wave."[38] For example, the position of a pendulum moving back and forth can be described using a sine wave: it seems to continuously move up to maximum amplitude and then back down, without pausing. Again, on my interpretation, the point of maximum amplitude does not serve as an actual middle in Aristotle's sense and so the argument does not apply. The pendulum's motion is produced by the interaction between two causes: the tension force pulling the pendulum towards its pivot point and the downward force of the pendulum's weight. Neither force is directed at getting to the point of maximum amplitude. While it follows from the way that the pendulum's tension and weight interact that there will be points of maximum amplitude, these points themselves do not play any special explanatory role. They do not serve as termini to which the pendulum is moving or from which it begins its motion. The points of maximum

[37] This type of example was helpfully suggested to me by an anonymous referee.
[38] Graham 1999, 152, cf. 132

amplitude are also not continuing states or achievement that complete the pendulum's motion. So, once again, Aristotle's case for an interval of rest does not apply.[39]

More generally, then, in the case of any motion that does not involve multiple distinct termini, there need not be any interval of rest in between changes of direction. When multiple movers and the relative action of their powers explain why the mobile changes directions, the mobile's motion is not explained in terms of sub-motions and thus it need not have arrived at and then departed from any specific point. The argument that has been our focus does not rule such motions out.

On my reading of *Phys* VIII, Aristotle rules such cases out for other reasons. They are not continuous precisely because all these sorts of cases involve multiple causes of motion. In the case of the pendulum we have the tension pulling the pendulum towards the pivot point and the downward force of its weight; in the case of Socrates, we have the moving walkway and Socrates himself; and, in the case of the apple, we have the power of the thrower and the heaviness of the apple. Aristotle uses the multiple causes at work in such cases to maintain that they cannot count as continuous unified motions.

For Aristotle, projectile motions may appear continuous, because they consist of a series of contiguous motions with no temporal gaps in between, but they are not (*Phys* VIII 10, 267a13-14). To rule out their continuity Aristotle does not appeal to the sort of interval of rest reasoning he employs in VIII 8, but to the fact that, on his theory, the thing causing the motion is not one (VIII 10, 267a14-15). On Aristotle's theory of projectile motion, the original mover (e.g. the person throwing the apple) not only moves the

[39] Cf. Galileo 1954, p. 254.

projectile and the medium immediately surrounding it (e.g. the surrounding air), it imparts its power of movement to the part of the medium it is in contact with (so the surrounding air now has a power to move the apple in the direction that the person threw it). (267a2-12) The apple is originally moved by the person's hand. After leaving the person's hand, however, the apple is moved by the air that was moved by the hand, which then imparts its power of movement to the air that is now in contact with the ball and so on. On Aristotle's view, when the power of movement cannot be fully imparted to each successive phase of the medium, the power of the medium's phases to move the projectile will gradually diminish. When this power is wholly gone, the projectile will cease moving (267a9-12).

Given this account, Aristotle maintains that the movement of a projectile is not continuous because the mover is not one thing, but a series of contiguous things (the original mover, followed by a contiguous series of phases of the medium). Aristotle's definition of continuous motion, given in V 4, 228b2-4 and referred back to in book VIII (e.g. VIII 8, 262a2-3), required that the motion be of one thing (ἑνός), where this requires that the thing being moved be one *and* that the mover be one. Projectile motion fails to meet this last condition. Similarly, the multiple movers involved in the case of the pendulum or Socrates on the walkway prevents them from meeting the definition. A lack of temporal gaps is not enough for continuity.

Aristotle carefully sets his own astronomy up to meet his conditions. While contemporary physics takes regular planetary orbits to be produced by the interactions of two bodies, with an elliptical orbit being the result of the interaction of the velocity, position, and mass of the sun with that of the planet, Aristotle's understanding is importantly different. For him, the motion of the heavens is produced by a number of spheres. Each sphere has its own unified motion that it continuously undertakes (though the motions of some of the inner spheres counteract the motion of some of the outer spheres) and each of these motions is produced by a single mover. (*Metaphysics* Λ 8, 1074a1-17).

Aristotle also appeals to the unity of motion in VIII 8 itself. At several points, Aristotle appeals to a principle about the unitary and harmonious goals of a continuous locomotion, with the clearest statement coming from the following passage:

> For everything which is moving continuously, if it is not put off by anything, was being borne earlier to what it went to by locomotion, e.g., if it went to B, it was also being borne to B, and not just when it was near, but as soon as it began to be moved; for why now rather than earlier? (264a9-14)

Here Aristotle is claiming that a continuously moving mobile can be said to be moving towards its goal for the whole time of the motion, from the very beginning to the end. For example, the runner moving from T to V can be said to be moving to V at any time during his run. On my view, Aristotle takes this to follow from his stipulation that a continuous motion be "the motion of one thing and in one time and in what is undivided according to species." (VIII 8, 262a2-3; cf. V 4, 228b2-4) If the mobile was only moving towards its goal in one part of the motion, then the other part of its motion would be of a different species, since it has a different goal, and motions are differentiated by their goals. We can formulate the general rule as follows:

> ***Always Goal-Directed***: the mobile, while engaged in continuous motion, can always be said to be moving towards every terminus of that motion.

Aristotle uses this rule to provide another argument that reflexive motion cannot be continuous (264a14-264b1) and also employs it to rule out constant flux (264b4-9).

This rule would prevent motions with multiple movers from being continuous. Either they have multiple different termini or they have no terminus. If they have multiple termini, then they would have to be always moving towards each of the termini, but they are not. In the case of reflexive motion, the mobile is first moving away from A and towards B and then moving away from B and towards A: the two phases have different and conflicting termini. In the case of complex rectilinear motion, the mobile is not moving down towards D while moving forward to B and vice versa. If, however, there are cases without defined termini, such as the motion of the pendulum or the apple, they, too, fail to be goal directed by lacking any goals or termini that define and delimit their motion. Thus they would not possess the kind of unified species necessary to count as continuous. On my reading, Aristotle's position here rests on different grounds than his argument about sub-motions.

So, on my interpretation, the **Changes are Open, Rests are Closed Rule** does not apply to cases of projectile motion or motions with multiple movers. Aristotle's claim that multiple interacting movers cannot produce a continuous motion succeeds or fails on a different basis. Aristotle requires a single motive cause and a single species of motion with a single goal for continuity and this rules such motions out. He does not, however, need to claim that such motions involve temporal interruptions.

K. Conclusion

Aristotle sums up his *Phys.* VIII 8 response to Zeno's dichotomy paradox in this way:

> So, to the one asking whether it is possible to go through infinite things (ἄπειρα), either in time or in length, one must say that in a way it is and in a way it is not. For if the things are in actuality (ἐντελεχείᾳ) it is not possible, but if they are in potentiality (δυνάμει) it is possible. For someone who moves continuously has gone through infinite things incidentally (κατὰ συμβεβηκὸς), but not without

> qualification (ἁπλῶς δ' οὔ). For it belongs incidentally to the line to be infinite halves, but its substance (οὐσία) and being (τὸ εἶναι) is different.[40] (VIII 8, 263b3-8)

We are now in a position to better understand Aristotle's response to Zeno. In one sense, Aristotle accommodates the classical modern response to Zeno: the mobile does go through infinitely many points in a way, since there is no limit to the number of points it occupies at different instants. This is what Aristotle means when he says that the mobile goes through the infinite δυνάμει, in capacity.[41] If we take Zeno as claiming that any motion is infinitely divisible, his claim is true, but unproblematic. If we take Zeno to be claiming that any motion is composed of an infinite number of actual motions, Aristotle insists that he is making a false claim. It would be problematic if it were true, but, in fact, a whole continuous motion cannot be composed of multiple actual motions. If Socrates were actually moving to the midpoint, he would have to arrive at and depart from the midpoint, necessitating rest.

To defend Aristotle's reasoning, I laid out his **Changes are Open, Rests are Closed Rule** and showed that it is consistent with his views on the beginning of change in book VI. On my interpretation of Aristotle's argument, he argues that the instant of arrival, the first instant at which the mobile has come to be at the actual middle, cannot be part of the subsequent time of motion. If it were, the mobile would be moving towards the next terminus and thus would need to have already left. This means that the instant of arrival must be separated from the time of departure by an interval of rest. My interpretation of the **Changes are Open, Rests are Closed Rule** allowed us to make

[40] The last line of this passage nicely brings out the fact that Aristotle's response here is in line with his general view about continuous things. For Aristotle the endpoints of a line are there in actuality, but the points in between are there in potentiality, they are not there in full actuality until the line is divided. Cf. *Metaphysics* Δ 11, 1019a7-11.

[41] Cf. Coope 2012.

good sense of the text of Aristotle's argument for thinking that the mobile must stop at an actual middle. I then showed how Aristotle's reasoning applies generally to rule out any continuous reflexive motion or continuous complex rectilinear motion. On my interpretation, however, the argument does not apply to every change of direction. When, as in the case of projectile motion, multiple movers and their relative powers explain why the mobile changes directions, distinct sub-motions are not involved. Aristotle holds that such motions cannot be continuous, not because they involve intervals of rest, but because they involve multiple causes of motion.

Aristotle is correct about the implications of his views on change: his rule implies that there cannot be successive actual sub-motions without intervals of rest. Given that most interpreters take Aristotle's position to beg the question or rest on a premise that is obviously mistaken, this is meaningful interpretative progress. By providing an account of Aristotle's reasoning based on a rule that follows from his general account of change and also has some intrinsic plausibility, I have shown that Aristotle's position is more defensible and plausible than commentators currently acknowledge, even if the rule on which he relies can be challenged. Aristotle's view of change implies that continuous motions cannot be composed out of multiple actual motions with different termini. In a truly continuous motion, the mobile does not actually arrive at and depart from each half-distance but goes through them all in capacity (δυνάμει) by going through the whole distance and actually arriving at the end.[42]

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