Alexander of Aphrodisias and John Philoponus on Projectile Motion*

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Περίληψη_ **Ιωάννης Παπαχρήστου | Η κίνηση των ριπτουμένων σωμάτων στον Αλέξανδρο Αφροδισιέα και στον Ιωάννη Φιλόπονο**

Στις παρεκβάσεις για τον τόπο και το κενό που συναντάμε στο υπόμνημα του Ιωάννη Φιλόπονου στα *Φυσικά* του Αριστοτέλη οι πηγές αλλά και οι αντίπαλοί του παραμένουν στη σκιά της ανωνυμίας και συχνά οι σύγχρονοι μελετητές επιδίδονται σε μια προσπάθεια αποκάλυψής τους. Η παράφραση του Θεμίστιου στα *Φυσικά* του Αριστοτέλη αποτελεί πολύτιμο βοηθό στο να ξεδιαλύνουμε αρκετές από τις πηγές και τους στόχους του Φιλόπονου σχετικά με τη θεωρία του για τον τόπο και την κίνηση των σωμάτων. Η παρούσα μελέτη εμβαθύνει στην αναζήτηση των συνομιλητών του Φιλόπονου γύρω από το ζήτημα της κίνησης των ριπτουμένων σωμάτων, που τον οδήγησε στη διατύπωση της έννοιας της εντυπωμένης κινητικής δύναμης στα σώματα (ευρύτερα γνωστής με τον λατινικό όρο impetus). Συγκεκριμένα επικεντρώνεται στον σημαίνοντα ρόλο της Περιπατητικής παράδοσης, ιδίως του Αλέξανδρου Αφροδισιέα και του Θεμίστιου, για τον σχηματισμό της θεωρίας της εντυπωμένης κινητικής δύναμης του Ιωάννη Φιλόπονου.

Introduction

John Philoponus adds to his exegesis of Aristotle's *Physics* Δ.8 an excursus, which one may name *On the motion of projectiles*. This critical observation is well-known because Philoponus formulates the theory of impressed power related to forced motion of projectiles, also called impetus theory (*in Phys.*, 642.3-26). Philoponus' impetus theory posits the existence of a bodiless impressed motive power imparted on the projectile by the mover.[1] The bodiless

* I am indebted to my teacher Prof. Christian Wildberg for commenting on an early version of this paper and the colleagues Keimpe Algra and Pantelis Golitsis for their useful suggestions.

[1] Philoponus says: ἀλλ' ἀνάγκη κινητικήν τινα δύναμιν ἀσώματον ἐνδίδοσθαι ὑπὸ τοῦ ῥιπτοῦντος τῷ ῥιπτουμένῳ, *in Phys.*, 642.4-5. What we call 'impetus', Philoponus calls it 'motive power' (κινητικὴ δύναμις) or 'activity' (ἐνέργεια).

moving power is directly transmitted by the mover to the projectile. Nothing intermediary plays any role in the transmission of that power. The main empirical presupposition of the theory is that the mover is in contact with the projectile. The medium through which the motion of the projectile happens contributes nothing to that motion or if it does, the medium intervenes only a little in the motion of the projectile. The excursus establishes the impetus theory as a correction to the interpretations of the problem as presented by Aristotle, expressed by Alexander of Aphrodisias and Themistius and, furthermore, it suggests that forced motion can happen through the void.

The impetus theory was further developed by other philosophers and physicians after Philoponus in Medieval and Renaissance times, such as Buridan, Oresme and Galileo.[2] Scholars read the corollary on the impetus theory focusing on the importance and the impact of this concept on theories of motion beyond late antiquity.[3] Yet, a question to posit is how did Philoponus arrive to the conception of the impetus? The roots of Philoponus' theory and the role of his predecessors, namely Alexander of Aphrodisias and Themistius, in the formation of the impetus theory appears to have attracted little attention in modern scholarship.[4] Alexander of Aphrodisias is considered as a figure that Philoponus confronts in his commentary on the *Physics* and Themistius' paraphrase of the *Physics* lies behind various passages of his commentary as a whole but also behind the excursus *On the motion of projectiles* on which we will focus.[5] The main claim of this paper is that Philoponus is inspired by the

[2] See, Grant 1964; Grant 1965; Wolff 2010; Krischer 1994; Fritsche 2011.

[3] Böhm (1967, 123–31 and 139–40) makes no reference to the unity of Philoponus' theory of place and motion through void. However, he points out philosophers that suggested the motion in the void before Philoponus, as for instance Chrysippus, Hipparchus and Chalcidius. Wolff's (1971, 46–52) significant treatise *Fallgesetz und Massebegriff* underlines the relation between the impetus theory and the digression on the void of Philoponus' commentary on the *Physics* but he mainly emphasizes the impact of the impetus theory on cosmological views. Sorabji (1988, 239–46) discusses the impetus theory with respect to natural and unnatural motion. Golitsis (2008, 188) refers to the impetus theory as based on Philoponus' views on place (and void) but provides no additional comments.

[4] Sorabji (1988, 223–24 and 2012, 327) points out Alexander of Aprhodisias' influence on Philoponus' theory of the natural motion of the elements suggesting that the natural internal impulses (or inclinations) of the simple bodies are the causes of the upward or downward motion. Sorabji also points out that Philoponus' divine impetus should be related to Alexander's view that the generator is not an external cause of motion but rather the one who "produces its internal constitution" (1988, 224).

[5] Philoponus uses the paraphrase on the *Physics* in the composition of the comments (level of exegesis). At this level Themistius plays the role of the interpreter of the Aristotelian text representing the Peripatetic tradition. Many times, Philoponus incorporates Themistius' text without naming him. But sometimes Philoponus presents a paraphrase of Themistius' paraphrase, by naming him. In the digressions on place and the void of the commentary, Philoponus deals with Themistius in both a friendly and a hostile manner. Usually, Philoponus does not name Themistius in the digressions. Many arguments that do not have a clear attachment with Aristotle's text

assumptions of Alexander of Aphrodisias, repeated by Themistius, in the development of the impetus theory, since they admit that a proper power is given by the mover to the air and successively to the projectile.

1. Aristotle on projectile motion

Before moving on to the reception of the problem of the motion of projectiles in late antiquity, one needs to begin by clarifying the origin of the topic, namely Aristotle's account. The discussion on the void in *Physics* Δ.8 partially examines the role that some philosophers assign to the void with respect to motion. Some of the physiologists (οἱ φυσιολόγοι) hold that there exists a separate, self-subsistent void and some others also maintain that the void is necessary for the locomotion of bodies. Aristotle attacks both assumptions but I am interested only in the latter assumption stating that the void is a necessary condition for locomotion. Aristotle introduces seven arguments (some of them are subdivided into sub-arguments) to show that locomotion through the void is impossible.[6]

One of these arguments states that forced motion (ἡ βίαιος κίνησις) presupposes natural motion (*Physics*, 215a1-14). The motion of projectiles through the void, used by Aristotle as the example of forced motion, is impossible because natural motion through the void is proved to be impossible. Aristotle introduces numerous cases to show that motion through void is impossible, but the commentators pay more attention to this one. The motion of projectiles, i.e. of bodies that move without being in contact with the thrower (ὁ ὤσας), happens under two circumstances. This kind of forced motion happens either by interchange of bodies (ἡ ἀντιπερίστασις), i.e. the projectile moves because the surrounding bodies are interchanging positions, or by pushing the air next to the projectile and causing a further motion of the projectile combined with the motion to its natural place.

According to Aristotle, both solutions are impossible in the void for the same reason: there is neither interchange of bodies in the void nor air to push it; thus, motion will be impossible.[7] We should note that Aristotle does not explain what the 'interchanging of bodies' means. The *antiperistasis* concept apparently reflects the view of some people, but no commitment to it on Aristotle's part is clear.[8] Nevertheless, I take it that Aristotle takes it as a plausible suggestion that could explain the forced motion of projectiles. The second way of understanding the motion of projectiles, as described above, seems to be

and are not explicitly stated as attacking Themistius, they do refer to Themistius.

[6] Aristotle, *Physics*, 214b28–216a23.

[7] Aristotle, *Physics*, 215a14-19.

[8] Golitsis (2018) examines in detail the concept of *antiperistasis* in Aristotle's discussion about the motion of the projectiles.

Aristotle's explanation but still there is no strong evidence for this in the passage discussed here, that is *Physics*, 215a1-14.

Aristotle returns to the problem of projectile motion in *Physics* Θ.10 (266b28–267a20). There, he clearly expresses the problem regarding the projectiles: how do we explain that the projectile continues its motion without being in contact with the mover?

> εἰ δ' ἅμα κινεῖ καὶ ἄλλο τι ὁ κινήσας, οἷον τὸν ἀέρα, ὃς κινούμενος κινεῖ, ὁμοίως ἀδύνατον τοῦ πρώτου μὴ ἁπτομένου μηδὲ κινοῦντος κινεῖσθαι, ἀλλ' ἅμα πάντα <καὶ> κινεῖσθαι καὶ πεπαῦσθαι ὅταν τὸ πρῶτον κινοῦν παύσηται, καὶ εἰ ποιεῖ, ὥσπερ ἡ λίθος, οἷόν τε κινεῖν ὃ ἐκίνησεν. (*Physics*, 266b30–267a2)
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> If we say that the mover in such cases moves something else at the same time, e.g. the air, and that this in being moved is also a mover, then it will similarly be impossible for this to be in motion when the original mover is not in contact with it or moving it: all the things moved would have to be in motion simultaneously and also to have ceased simultaneously to be in motion when the original mover ceases to move them, even if, like the magnet, it makes that which it has moved capable of being a mover. (transl. Barnes 1984, 159–60)

The context of *Physics* Θ.10 relates to the nature of prime movers; however, this passage illuminates the discussion in *Physics* Δ.8 regarding the motion of the projectiles. Aristotle argues that the prime mover (in this case a man who is the relevant initial moving cause) moves the body, say a rock, and it also moves the air along with it. The projectile (rock) and the air are of those beings that may naturally be moved by a mover. However, the fact that the projectile moves without being in contact with its mover requires an explanation. Aristotle says that the projectile will stop moving only because the given power of motion continuously diminishes. He wishes to clarify, first, the cases in which prime mover and moving bodies are either at rest or move; second, he attempts to explain why the projectiles move after leaving their mover. However, it is totally unclear how the air is moved by the mover and how this relates to the motion of the projectile.

Aristotle rather describes the stages of the forced motion from its starting point (prime mover) to its end (fall of the projectile to its natural place). He notes that the motive force (ἡ δύναμις τοῦ κινεῖν)[9] of the mover takes place

[9] The expression 'motive force' is equivalent to the term 'κίνησις' in this passage. Aristotle phrases it twice in the text saying, 'the motive force produced in one member of the consecutive series' and 'the motion takes place in bodies', *Physics*, 267a8-9 and 267a12-13. So, according to Aristotle, what is transmitted to the air and the projectile is motion (κίνησις), not some other kind of force.

in the body next to the mover (ἐγγίγνηται τῷ ἐχομένῳ), say the air, which is by its nature capable to move and to be moved. Aristotle asserts that there is a successive transmission of a moving force that gradually diminishes, as it is transmitted from a first mover to successive moved movers, until there remains only something moved, with which the whole motion ceases:

> παύεται δέ, ὅταν ἀεὶ ἐλάττων ἡ δύναμις τοῦ κινεῖν ἐγγίγνηται τῷ ἐχομένῳ. τέλος δὲ παύεται, ὅταν μηκέτι ποιήσῃ τὸ πρότερον κινοῦν, ἀλλὰ κινούμενον μόνον. ταῦτα δ' ἀνάγκη ἅμα παύεσθαι, τὸ μὲν κινοῦν τὸ δὲ κινούμενον, καὶ τὴν ὅλην κίνησιν. (*Physics*, 267a8-12)
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> The motion ceases when the motive force produced in one member of the consecutive series is at each stage less, and it finally ceases when one member no longer causes the next member to be a mover but only causes it to be in motion. The motion of these last two –of the one as mover and of the other as moved– must cease simultaneously, and with this the whole motion ceases. (transl. Barnes 1984, 160)

So, Aristotle seems to defend the explanation that the forced motion of the projectile happens by pushing the air next to the projectile and causing a further motion of the projectile combined with the motion to its natural place. When the motive force gradually diminishes, the projectile continues to move to its natural place, i.e. the rock will move downwards. In *Physics* Θ.10, Aristotle also comments on the viewpoint that the interchange of bodies during the forced motion of projectiles plays a role (*Physics*, 267a15-17; 18-20). This view[10] presupposes that the motion of the projectile always happens either through the air or the water in order to have an interchange of bodies (ἀντιπερίστασις). Aristotle argues that the solution of interchange of bodies makes all the constituents of the forced motion (i.e. prime mover, air/water, projectile) to move and to be moved at the same time; consequently, they are at rest at the same time. But in the case of a projectile's motion we only observe that one body (which is not self-moved by nature) continuously moves because it is always in contact with another body. The point of Aristotle's discussion of *antiperistasis* here is to save his essential assumption that everything that is

[10] It seems that Alexander of Aphrodisias attributes this view to Platonic circles (οἱ περὶ Πλάτωνα, Rashed 2011, fr. 810, 637; see Plato's *Timaeus*, 80a1-2. Simplicius too reports that Alexander attributes this view to Plato (*in Phys.*, 1351.28-29; 668.25-669.2). Simplicius is unclear on whether Alexander had a specific argument against Plato's or not (*in Phys.*, 1351.28–1352.18). Another excerpt of Alexander's lost commentary shows that Alexander does not consider the interchanging of bodies as the cause of the forced motion but rather as a symptom (Rashed 2011, fr. 811, 637). It appears that Böhm (1967, 135) and Golitsis (2008, 188) attribute the view of interchangeability to the Peripatetics and Aristotle respectively (note that Golitsis later changes his view claiming that the interchange of bodies is not an Aristotelian view; see Golitsis 2018, 4 and 9). Sambursky (1987, 75) points out that the commonly accepted concept of bodies interchanging places was rejected by Aristotle.

in motion is moved by something. An assumption that Philoponus' impetus theory repudiates, as we shall see.

On the one hand, Aristotle finds plausible the view of interchange of bodies but, on the other hand, he seems to be reluctant to endorse this view. Aristotle's suggestion attempts to explain the motion of projectiles implying that the prime mover transmits the motive force to the medium which moves along with the projectile. The motion of the projectile is thus explained by the fact that at least one part of the medium needs to act upon the projectile as a mover, until the projectile finally falls to its natural place. Aristotle explicitly states that this is the only explanation solving the problem.[11] However, some commentators of Aristotle's *Physics* seem not be persuaded by the explanation and come up with some questions repudiating his attempt to explain the motion of the projectiles.

2. Alexander of Aphrodisias and Themistius on projectile motion

We have seen that Aristotle only refers to the plausible ways in which the forced motion of projectiles may happen, without any additional justification. Simplicius reports Alexander of Aphrodisias' view on this matter.[12] Alexander seems to be unsatisfied with Aristotle's claim that the motive force takes place in the body next to the mover (*Phys*., 267a8-9). He then attempts to explain Aristotle's thought by providing a plausible solution fitting the natural world. It is not enough to say, according to Alexander, that the air receives the motive force from the mover; for, in this case, the air will not be able to move something else when it doesn't move.[13] It is perhaps better to say that the air possesses a proper force (οἰκεία δύναμις) received by the mover. For if we admit that the air has a proper force, we could explain why the air continues to cause motion without being a self-moved body (αὐτοκίνητον). So, the air somehow becomes a self-moved body for some moments. This is a crucial point. The air receives by the mover the motive force (called τὸ ἐνδόσιμον)[14] which now is possessed by the

[11] See Aristotle, *Physics*, 267a17-18. Hussey doubts that there is any clear statement from Aristotle's part concerning the projectile motion. In fact, Hussey (1991, 230–36), denies that there is an Aristotelian theory of projectile motion at all. It is true that we can only speculate about a coherent explanation of projectile motion, according to Aristotelian physics, since we lack a fully elaborated argument by Aristotle. The failure of Aristotle to explain the projectile motion has been also stressed by Sambursky (1987, 70–71).

[12] Simplicius, *in Phys.*, 1346.29–1347.37. Simplicius notes that he almost copied word for word Alexander's view obviously from his lost commentary on the *Physics* (ταῦτα πάντα σχεδόν τι κατὰ τὴν τοῦ Ἀλεξάνδρου λέξιν ἀπεγραψάμην, Simplicius, *in Phys.*, 1347.37-38). Indeed, an excerpt of Alexander's view that matches Simplicius' report can be found at Rashed 2011, 634, fr. 805.

[13] See, Simplicius, *in Phys.*, 1346.29-35.

[14] Simplicius uses the word τὸ ἐνδόσιμον, taken up by Themistius' text (*in Phys. paraphr.*, 235.7-12), in order to describe the transmission of the force from the mover to both the air and

air, therefore it is as if the air were a self-moved body or as if it had a proper force to move by virtue of being easily affected (δι' εὐπάθειαν).[15] As long as this affection lasts,[16] the air around the projectile continues to move without being in contact with the mover and at the same time it moves the projectile.

Aristotle, as we pointed out, claims that a projectile continues to move because of a succession of moving movers. Alexander's motivation is to show that the air should possess a proper force that makes it to move for a while as a self-moved body which is capable to move the projectile. Alexander's claim introduces a novelty, according to Simplicius, namely that of the air acquiring by the mover the principle and the motive force (τὸ ἐνδόσιμον) to be moved and to move something else. Yet, Alexander's explanatory model is not the novelty here, since there is no difference with the Aristotelian model, but, as we shall see later, the idea of *possessing* the proper power (οἰκεία δύναμις) will be proved of great importance for Philoponus to change this explanatory model.[17]

Themistius bases his approach of the problem on the grounds of Alexander's explanation.[18] He refers to the explanations which Aristotle expressed (215a14-19), namely the ἀντιπερίστασις and the air that pushes the projectile while it is moved. The explanation for the procedure of interchange of bodies, given in the paraphrase, maintains that the air which is in front of the projectile changes place because of the rush of the body in motion (ὑπὸ τῆς ῥύμης, *in Phys. paraphr.*, 129.21), then it goes behind, pushing the projectile for a limited time, until the force becomes loose. There is no reference to the holders of this view; not even a hint as to who supports it. Themistius presents it as a general explanation of the interchange of bodies.[19]

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the projectile. We have no clue if this is the exact term Alexander of Aphrodisias originally used. The term τὸ διαδόσιμον appears in the passage we possess in Rashed's edition (2011, fr. 805, 634), but still the term refers to warmth transmitted to objects. The word τὸ ἐνδόσιμον literally relates to music meaning 'that which gives the key to the tune, the key-note' (see, Liddell–Scott [8]1897, 476) but this meaning doesn't seem to shed light on the philosophical context.

[15] Alexander's claim could be a direct reference to Aristotle's *De caelo*, 301b17-31, where the air is considered as an instrument explaining the forced motion of projectiles due to its receptivity of bodies' lightness and heaviness.

[16] The text transmitted by Simplicius gives: ἕως οὖν τὸ πάθος σῴζει, *in Phys.*, 1347.29.

[17] Simplicius says: τὸ τῆς λύσεως καινοπρεπές, *in Phys.*, 1348.1.

[18] Themistius' *In Aristotelis Physica paraphrasis* is thought to be a philosophically poor text which blends Aristotle's words simplifying their meanings. However, Themistius himself understands his paraphrases in a slightly different manner; he paraphrases the Aristotelian text but he also insists to provide exegesis in various cases. In fact, his exegetical notes on Aristotle's text aim to clarify the arguments (see, for example, Themistius, *in Post. An.*, 1.16-22). But clarifications of arguments may well turn out to be original thoughts, as Kupreeva (2010, 400) notes: 'Occasionally, Themistius makes an *excursus* from paraphrasing to state his position or discuss a more controversial question. These digressions are most important for reconstructing his philosophical views'.

[19] Themistius, *in Phys. paraphr.*, 129.15-27.

The second explanation of the motion of projectiles, that is more likely to be supported by Aristotle, is presented as follows in Themistius. How does the projectile move without being in contact with the mover? For it is obvious that the projectiles, for instance arrows, are neither self-moved (αὐτοκίνητα) nor are they in contact with their mover anymore because it is at rest after the projectile leaves it. The projectile continues to move without being in contact with the mover because the air is pushed by the mover, as if it were forced together with the projectile, and it continuously flows together with the projectile. According to Themistius, the reason why the projectile continues to move is that air is easily moved; the air receives the principle of motion by the mover and moves forward for a while keeping the motion applied to it. The air moves fast along with the projectile which moves towards its proper place, as the force of motion in it given by the mover diminishes; for instance, we observe that an arrow moves downwards because it is a heavy body.[20] But Themistius observes that simply saying that the archer moves the air and that the air moves along with it the arrow is an unsatisfactory solution. The problem is not solved but rather transposed. For we then need to explain the fact that the air moves without being in contact with the mover.[21]

Themistius suggests a solution to the problem of projectile's motion that echoes Alexander of Aphrodisias' exegesis. He holds that the air and the arrow continue to move after leaving their mover because they were given a certain force (δύναμις) which is not any more the direct force of the mover, but their proper force (οἰκεία δύναμις), though transmitted by the mover.[22] Themistius also provides us with an example. An iron stone becomes warm because of the fire but it still keeps the force of the warmth for a longer time after the fire has been removed; in this way, the iron stone can transmit the warmth to another body that is in contact with it and even other bodies that are in contact with the first body. This may go on until the force of the warmth that has been given to the iron stone by the fire diminishes in the succession of its transmission.[23] The same holds for the motion of the air and that of the projectile. Someone might say that the mediums share the properties of forces (ἐπαμφοτερίζοντα) and partake of weight and lightness. When they receive the principle of motion (τὸ ἐνδόσιμον), they move, as if they were self-moved bodies, along with the projectile for some time by their proper force. The significance of this view centers on the fact that we do have a more substantial explanation of projectile motion in contrast to the Aristotelian text which left the question unsettled.

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[20] Themistius, *in Phys. paraphr.*, 129.23-26.

[21] See, Themistius, *in Phys. paraphr.*, 234.11–235.29. Especially the passage *in Phys. paraphr.*, 234.17-19 follows Aristotle's argument *in Phys.*, 266b30-33.

[22] See Themistius, *in Phys. paraphr.*, 235.4-16. Themistius already in book Δ.8 says τὴν ἐνδοθεῖσαν κίνησιν διαφυλάττων, *in Phys. paraphr.*, 129.25, explaining Aristotle's phrase ἡ δύναμις τοῦ κινεῖν ἐγγίγνηται, *Phys.*, 267a8-9.

[23] The example clearly goes back to Alexander of Aphrodisias. See Rashed 2011, 634, fr. 805.

Themistius adopts and summarizes Alexander's view without mentioning Alexander.[24] Simplicius' testimony also helps to identify Themistius' source behind the words of the paraphrase of *Physics* Δ.8, where the air is characterized as agile (εὐκίνητος); a phrase which represents Alexander's expression (*apud Simplicium*) of being easily affected (εὐπαθής).[25] Themistius comprehends the easily affected nature of the air as agility. In addition, he argues that the air moves forward for a longer time, after it leaves the mover, by saying that "it [the air] keeps the motion which has been given to it" (*in Phys. paraphr.*, 129.25). This sentence should be Themistius' adoption of Alexander's crucial feature of his interpretation that the air in a way moves, as if it were a self-moved body.[26]

Up to this point, we saw that Alexander of Aphrodisias attempted to elucidate Aristotle's vague explanation, for it proved to be rather insufficient. Alexander's solution to the motion of projectiles implies that the medium moved by the mover possesses a force capable of moving the projectile. Though not clearly deviating from Aristotelian physics, since he is not refuting Aristotle's assumption that everything that is in motion moves by a mover and it is in contact with the mover, Alexander establishes the feature of the possession of the force of motion. The idea is clearly incorporated in Themistius' text, who recognized too that Aristotle failed to plainly explain the motion of projectiles, as shown above. In this context, Simplicius is right to say that Alexander introduces a novelty. Even though far from expressing an impetus theory, Alexander's view that the air plays a role in the motion of projectiles because of *possessing* the force of motion given to it by the mover is perhaps the most important instance in the history of the problem of projectile motion after Aristotle and before Philoponus, as it will be stressed in what follows. Philoponus was aware of this discussion through Themistius and even if Aristotle is responsible for this explanatory gap, Philoponus mainly turns against Alexander's interpretation, the only prominent explanation that has been carried out by Aristotle's followers. Therefore, the *Corollary on the motion of projectiles* begins with Philoponus' reasons for criticizing Aristotle, though he attacks the refined arguments developed by Alexander and reproduced by Themistius.[27]

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[24] Themistius, *in Phys. paraphr.*, 234.27-235.12.

[25] See in parallel Themistius, *in Phys. paraphr.*, 129.24-27, and Simplicius, *in Phys.*, 1347.6-8; 1347.29.

[26] Alexander says τὴν πρώτην αἰτίαν λαβὼν ἀπὸ τοῦ ῥίψαντος καὶ τρόπον τινὰ αὐτοκίνητος γεγονώς, Rashed (2011, 634), fr. 805.

[27] Philoponus reports that he also criticized the speculations on the projectile motion in his commentary on *Physics* Θ (see, *in Phys.*, 639.7-9). I suspect that the *Corollary on the motion of projectiles* in the comments on *Physics* Δ is only a short version of the criticism exposed in the commentary on *Physics* Θ perhaps in a more substantial corollary. Unluckily, Philoponus' commentary on book Θ is lost.

3. John Philoponus against Aristotle and the Peripatetic tradition

Philoponus' second lecture on *Physics* Δ.8 deals with Aristotle's assumption that motion of projectiles is impossible through the void.[28] This lecture contains two sharply distinctive parts; the exegetical and the critical part. The exegetical part (*in Phys.*, 636.25–639.2) of the lecture is one of the characteristic examples of silent incorporation of Themistius' exegesis in Philoponus' text. In fact, the passages taken out of Themistius' paraphrase are those introducing the problem of projectile's motion and its explanation.[29] A closer reading of the exegetical part of this lecture will show Philoponus' intentions to draw attention directly to the problematic theory held by Alexander and Themistius regarding the projectile motion. I will mainly discuss his critique against the Peripatetic view.

Philoponus' attack in the corollary has a double goal. First, he aims at correcting the Aristotelian tradition concerning the motion of projectiles; second, he wants to support the view that the motion of projectiles is possible in a void. The former goal repudiates the validity of the arguments held by the Peripatetics, especially by Alexander of Aphrodisias and Themistius. With the latter goal Philoponus offers a reply to Aristotle's general thesis of the impossibility of forced motion through the void.[30]

Firstly, Philoponus provides us with two versions of the ἀντιπερίστασις view. I will not fully analyze his rejection of the *antiperistasis* theory, but I would like to point out the following. The first version implies that when the projectile moves, the air in front of it runs back behind it and pushes it (as described by Themistius). This particle of air occupies the position previously occupied by the projectile and pushes the projectile until the impulse diminishes. Philoponus considers the assumption that the air runs back and continues to move forward as if by a command,[31] without being scattered to the winds, as fictitious.[32] The second version of the interchangeability of bodies, of

[28] Philoponus, *in Phys.*, 636.25–642.26.

[29] See, Philoponus, *in Phys.*, 637.10–638.13 and Themistius, *in Phys. paraphr.*, 128.30–129.26. For our purposes, it is important to denote that Philoponus' citation of Alexander of Aphrodisias' view, as presented by Themistius, shows that the direct target is the Peripatetic tradition and indirectly Aristotle.

[30] Criticisms related to points of the exegesis, i.e. discussing *ad hoc* problems arising from the Aristotelian text, is the main characteristic of every corollary in Philoponus' commentary on the *Physics*. For example, in this corollary Philoponus seems to criticize the view of *antiperistasis* by repeating Themistius' expression that the air is easily movable (εὐκίνητος), and he insists that the important factor of the motion of projectiles is the principle of motion transmitted by the mover to the air (*in Phys.*, 639.27–640.5).

[31] ὥσπερ ἐξ ἐπιτάγματος, *in Phys.*, 640.2.

[32] The Ms Laur. Plut. 87, 6 has a note *in margine* dating from 13th or 14th century. This note attempts to explain how the *ἀντιπερίστασις* works. Apparently, the note justifies a certain kind of

unknown source, suggests that the interchange of place between the arrow and the air happens because the air at the side is moved by the air in front (*in Phys.*, 640.26–641.6). For Philoponus, this version does not imply a continuous motion of the projectile but an instantaneous or interrupted motion. In brief, both versions do not sufficiently explain the forced motion of projectiles, according to Philoponus, who finds them rather naïve. The *antiperistasis* view explains how bodies interchange positions to one another during their motion,[33] but it cannot explain in what way the moving power transmitted to the medium finally moves the projectile.

Let us see now how Philoponus rejects the explanation of projectile motion proposed by Alexander and endorsed by Themistius. Aristotle, as we saw, asserts that the motion of projectiles happens because the mover transmits the principle of motion to the air that moves the projectile until its motion diminishes. Alexander of Aphrodisias, followed by Themistius, maintains that Aristotle's theory makes sense if we admit that the air possesses a proper force (οἰκεία δύναμις) received by the mover. Philoponus considers Alexander's explanation as unsuccessful because it asserts, like Aristotle's, that the mover transmits the moving power (ἡ δύναμις τοῦ κινεῖν, *Phys.*, 267a8-9) to the air but without clarifying the exact role of the medium regarding the motion of the projectile. Is it the case that the air is responsible for the subsequent forced motion of the stone after it departs from the mover?[34]

There should be, Philoponus argues, a kind of moving power directly given to the projectile by the mover. Otherwise, if the air is responsible for the motion of the projectile, it is not necessary for the mover to be in contact with the projectile; air alone could be enough to move the projectile. The example

antiperistasis which is not as problematic as Philoponus thinks. The writer of this comment uses the example of a sailing boat. When the water sails by fair winds, the water interchanges place with the water at the stern of the boat. The boat forcibly cuts the water providing way to the water which always comes to the stern of the boat. The commentator argues that the water coming to the stern of the boat either plays a minor role or it is completely irrelevant to the motion of the boat. The same, he adds, happens in the case of the arrow moving through the air. The point of the comment is unclear. It implies that parts of water interchange places to one another during the motion of the boat. However, it fails to escape Philoponus' critique, for it does not explain how the specific particle of water in front of the boat comes directly behind the stern of the boat. The example of the boat may be a good example, if one wants to explain how the interchange of places among bodies happens. Yet this example does not explain how a projectile moves, since the sailing boat is not a projectile, though it undergoes a kind of forced motion, since the boat is not a self-moving body. Nevertheless, the comment contains a significant detail, namely that the water plays a minor or no role to the motion of the boat, as in the case of the air and the arrow. Philoponus endorses the assumption, for he believes that the medium through which the projectile moves is not responsible for the continuous motion of the projectile while it is not in contact with the mover.

[33] Philoponus and Themistius agree on that point.

[34] Philoponus, *in Phys.*, 641.13–642.2.

provided by Philoponus hypothesizes that one can obtain forced motion of a projectile just by producing strong air behind the projectile using artificial means.[35] Then we could say that the projectile is pushed further by the air which is strongly forced to move. But does this hypothesis appear to be compatible with reality? If we put a stone on a line or spot with little breadth, and then try to move the air with great force, we will observe that the stone will only move for an extremely short distance. In cases of forced motion where the mover is in contact with the projectile, the air itself cannot be the mover of the projectile. Since the hand is in contact and continuous with the stone, there is no place for a medium in between, let us say air, which may be moved; consequently, Philoponus argues, the medium does not play any active role in the movement of the projectile.[36]

The solution held by Alexander and Themistius asserts that a medium is always involved in the motion of projectiles. Both Alexander and Themistius hold that the medium possesses the power of motion transmitted to it by the mover. This power of motion in a way becomes, as we saw, the proper power of motion of the medium which is further transmitted to the projectile. Therefore, the air resembles a self-moved body. Here, I would like to stress that Alexander's view, quoted by Simplicius, contains the seed of the concept of the impressed power. Alexander's argument presupposes two assumptions: first, that the air possesses a motive force; and second, that this motive force undergoes a succession of transmissions from the primary mover to the projectile.

As far as the first assumption is concerned, I argue that the possession of the moving force, i.e. τὸ ἐνδόσιμον, by the air amounts to the concept of the impressed power and it is what inspired Philoponus to grasp the conception of the impetus. The reason for this is that the power that becomes 'the proper power of the air' is an ἐνδόσιμον. The term means, in this context, that the power is given to the air in the sense that the power belongs to the air, or it is possessed by the air. Alexander does not describe a case of something instantaneously forced, but rather of a power that persists in the air for a while until it diminishes. In other words, the motive power is impressed on the air by the

[35] Philoponus hypothesizes something impossible in order to prove what happens in reality; on such kind of hypotheses in Philoponus see Martin 1999. This kind of hypothesis is a type of thought experiments often used in the commentary on the *Physics*. Here Philoponus brings into play artificial means capable of producing strong air. But Philoponus knows that it is impossible to move the stone by producing air behind it for a long distance. Further, he is not considering the case of machines producing air as a proper case of motion of projectiles. It is quite intriguing to clear up whether Philoponus refers to real machines (μηχαναῖς) or to machines theoretically established in mechanics, but this issue exceeds the purposes of the present paper. However, I would like to contribute a piece of evidence to a future research: Lewis (2007, 372) refers to Heron of Alexandria's windmills that, I only speculate, perhaps Philoponus may have had in mind (or, in addition, some kind of mechanical air pumps).

[36] See, Philoponus, *in Phys.*, 641.29–642.2.

mover. The second assumption admits that the air is not an unmoved mover; it belongs to the bodies that are easily moved. The example of the fire transmitting the warmth to other bodies next to it given by Alexander, also found in Themistius, shows that he accepts a kind of transmission of the power to the projectile. Within the framework of Aristotelian physics, the forced motion is considered as a continuous, successive motion of moving bodies that are not self-moved by nature (such as an arrow or a stone) and, therefore, need to be in contact with another body. So, Alexander insists on the fact that the air must be in contact with the projectile, i.e. pushing the projectile and transmitting to it motive power.

Philoponus' attack intends to show that the medium, through which the projectile moves, plays no role to the motion of the projectile. The Peripatetic tradition is falsely attached to the Aristotelian view that the medium decisively contributes to the motion of projectiles. On the one hand, Philoponus clearly eliminates the role of the medium in the motion of projectiles and on the other hand, he complies with the concept of the proper motive power transposing it from the medium to the projectile; the projectile possesses the bodiless impressed power given by the mover and therefore it moves for a while without being anymore in contact with its mover. Further evidence for this is the constant use of the concept of τὸ ἐνδόσιμον in the verbal form ἐνδίδοσθαι, present in Themistius too, throughout the passage introducing the impetus theory. Philoponus repeatedly claims that there is a power *given to* (or impressed on) the projectile by the mover. This kind of power is possessed by the projectile for a while until it falls to its natural place, in the same way as Alexander thinks that the moving power is possessed by the air, although the explanatory model of the Peripatetic tradition fails to conceive the impetus theory.

Conclusion

Philoponus repudiates Aristotle and the Peripatetic tradition on the basis either of observations or thought experiments rooted in common experience. The point of the whole criticism is to stay close to the facts: the projectile motion exclusively relies on the relationship between the mover and the projectile. The mover, according to Philoponus, must be in contact with the projectile and they are continuous to one another, when the power is transmitted, so the medium through which the projectile moves cannot be the cause of the motion. The impetus theory suggests a further cause of motion of projectiles (apart from their natural impulse), namely an impressed motive power which explains the motion of the projectile after it gets separated from the mover. The impressed motive power transmitted to the projectile by the mover becomes the proper motive power of the projectile. Alexander of Aphrodisias did not grasp the conception of the impetus and failed to escape from the Aristotelian

model of the motion of projectiles. Philoponus is motivated by Alexander's assumption that the proper motive power is transmitted by the mover to the medium. He made a further step by holding that the projectile possesses this bodiless power directly impressed on it by the mover and therefore he is the first one to articulate the impetus theory in the history of science.

The parallel reading of Alexander of Aphrodisias' (*apud Simplicium*) and Themistius' arguments on the topic put forward for consideration the question of Philoponus' sources and influences.[37] Themistius, as we understand from Simplicius, obviously relies on Alexander's viewpoint; and if Themistius does not originally contribute to the solution of projectile's motion, on the other hand he is responsible for the transmission of a view that provoked Philoponus' critique. Philoponus' impressed power results from his intention to propose a more accurate theory of motion; a theory which above all should be in accordance with natural facts. It becomes clear both from the exegetical and the critical part of the *Corollary on the motion of projectiles*, that had never been discussed together, that the impetus theory of Philoponus owes much to Alexander of Aphrodisias and that the close reading of these texts is essential to tracing the development of the impetus theory in late antiquity.

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[37] Simplicius, if we exclude his ironic stance, gives us a picture of Philoponus' use of sources, when he says that Philoponus uses Alexander's exegesis and Themistius' paraphrase in order to amaze his readers with the size and number of his books (*in Phys.*, 1130.3-7).

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