

# Renaissance Concept of Impetus\*

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## Abstract

The concept of impetus denoted the transmission of a power from the mover to the object moved. Many authors resorted to this concept to explain why a projectile keeps on moving when no longer in contact with its initial mover. But its application went further, as impetus was also appealed to in attempts to explain the acceleration of falling bodies or the motion of the heavens. It was widely applied in Renaissance natural philosophy, but it also raised a number of ontological questions concerning its precise nature.

## 1 Introduction

First formulated in late antiquity, the concept of impetus denoted the transmission of a power, a force (*vis impressa*) or a motive quality, from the mover to the object moved. Many authors resorted to this concept to explain why a projectile keeps on moving when no longer in contact with its initial mover. But its application went further, as impetus was also appealed to in attempts to explain the acceleration of falling bodies or the motion of the heavens.

Ever since Pierre Duhem drew attention to the importance of the concept for scholastic natural philosophy, it has occupied a central role in historiographic debates on the roots of the scientific revolution [6]. Anneliese Maier's seminal studies convincingly demonstrated the difference separating the scholastic concept of impetus from Newtonian inertia (see especially [12]), but it could still be seen as the starting point for a revolution that marked the distance from Aristotle and led to Copernicus and Galileo [10, 3]. In general, two opposing views can be singled out (with many options in between): (1) on the one hand, the concept of impetus is conceived as central to a specific, non-Aristotelian manner of understanding the causal order of nature, which starts with

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Philoponus and lasts until Galileo and Descartes [19]; (2) on the other hand, it has been claimed that a single shared concept of impetus does not exist, that there is rather an array of different and mostly ad hoc attempts to solve natural philosophical problems within the Aristotelian tradition by resorting to impetus [13]. Rather than trying to endorse one of these views, in what follows we will recall and put in context some of the main views on impetus and their fate in the Renaissance.

## 2 Heritage

### Aristotle

Aristotle only dealt with projectile motion in passing, when discussing other matters: the question of motion in the void (*Physics* IV.8), the manner in which the first mover causes the eternal motion of the heavens (*Physics* VIII.10), and the existence of natural motions (*On the Heavens* III.2). Even if it was only peripheral to his main interests, Aristotle still needed to offer an explanation for its continuing motion that was consistent with the rest of his natural philosophy. The crucial constraints were the principles that scholastic philosophy would translate as *omne quod movetur ab alio movetur*, meaning that everything that is moved is moved by another, and *movens et motum sunt simul*, according to which the mover of a body must be in contact with the latter to generate motion. Aristotle preferred the explanation according to which the projected body is moved by the surrounding air once it has left the hand of the projector. The air is not simply put into motion together with the body, but it also acquires a moving force which it then imparts both to the body and to neighbouring parts of the air. This process is repeated until the force is completely exhausted [13, pp.123-124]. As careful medieval and renaissance readers would later point out, this can be taken to imply that Aristotle did not doubt the idea of an impressed force, but primarily disagreed on its localization (see [11, passim]).

There is another place in the Aristotelian corpus where projectile motion is discussed, although in very inconclusive terms: questions 32-34 of the *Mechanical Questions* ([1] argues that these show that Aristotle or his immediate pupils were not completely satisfied with the account offered in the *Physics* and *On the Heavens*). It was only in the Renaissance that these passages would be linked to the concept of impetus (first by Alessandro Piccolomini and later by commentators such as Bernardino Baldi [2, pp.363, 365, 414-417]).

## Late Antiquity and Arab Philosophy

The first occurrence of the concept of impetus can be found in 6th-Century commentaries devoted to Aristotle's *On the Heavens* and *Physics*. Since the beginning, it was not only exploited to explain the continuation of projectile motion but also to describe the acceleration of falling bodies as well as the motion of the heavens.

Simplicius (490-560), in his commentary on *On the Heavens*, said that according to Hipparchus (an astronomer of the second century BC), a piece of earth that is thrown upwards continues its upward motion as long as the force impressed in it by the thrower is able to counteract the natural inclination to fall. When it starts to fall down, the earth still retains part of the impressed force, which gradually diminishes until it has completely disappeared, giving rise to the phenomenon of acceleration [15, p.349].

Another commentator, John Philoponus (490-570), opposed Aristotle on the explanation of projectile motion. In his view, the motive force is transmitted directly from the mover to the body moved. As a result, Philoponus held forced motion in the void to be possible, but he claimed that the impressed force will be extinguished after some time [20, p.130]. Philoponus also stated that God implanted a motive power in the heavenly bodies in the same way that he implanted in the elementary bodies an inclination to move towards their proper places. Impetus is thus extended by Philoponus to the heavenly realm [15, pp.351-355].

It is very likely that the Arab philosophers became acquainted with Philoponus' theory of impetus [4, pp.510-514]. Avicenna, who was probably the most influential author, identified three kinds of inclination (*mayl*): (1) psychic (*mayl nafsānī*); (2) natural (*mayl tabī'ī*); (3) unnatural or violent (*mayl qasrī*). The third genre of *mayl* intervenes when a body is thrown by force. For Avicenna, there cannot be more than one *mayl* in the same body at the same time. In this regard, his theory of impetus differs from the one Simplicius ascribed to Hipparchus. It differs also from Philoponus' view, for Avicenna holds that the *mayl* would last indefinitely if there were no medium opposing resistance. This seems to have been intended in the first place to show the nonexistence of the void, since he also adds that this infinite motion does not occur in nature [4, p.513].

## Medieval Scholasticism

Philoponus had already highlighted the empirical implausibility of the role that Aristotle assigned to the medium. Still, there were good reasons within Aristotle's natural philosophy to defend this explanation, as stressed by Thomas of Aquinas (1225-1274). According to Thomas, the projectile cannot receive an intrinsic principle of motion: if

this was the case, then the projectile motion would become natural rather than violent [4, pp.516-517][18].

The introduction of the impetus concept in scholastic philosophy is traditionally ascribed to Francis of Marchia (first half of 14th century), who held the Franciscan chair of theology in Paris, but recent scholarship has shown that there were some thirteenth-century predecessors [14]. Marchia's much more extensive discussion appears in his commentary on the *Sentences* when treating the question of sacramental causality: should we assume that there is some kind of instrumental force present in the sacrament, or does God work directly? In discussing the general problem of instrumental causality, he introduced the example of projectile motion as a crucial example, appealing to the idea that a *virtus derelicta* is left behind in the body [11, pp.45-77]. Marchia also tried to determine to what kind of quality this *virtus* belongs, qualifying it as a form that is "not simply permanent, nor simply fluent, but almost medial", staying for some time in the body, but then fading away [4, p.529]. Clearly, he tried to circumvent the worry raised by Thomas by assigning the impressed force an ontological category of its own. In a further comment, Marchia suggested that this same *virtus* could also be used to explain how the angelic intelligences move the celestial spheres [11, pp.67-73].

Jean Buridan (1295-1363) formulated what has been called the "classical" concept of impetus [13, p.134]. He quoted several empirical reasons to support the concept of impetus and he also gave some proportional indications about how it relates to factors such as the amount of matter that is put into motion [4, pp.521-523]. Contrary to Marchia, he claimed that the impetus was "a thing of permanent nature" [4, p.537]. His main reason for making this claim seem to have been the need to sharply distinguish the impetus from the motion it caused [12, pp.86-87]. The difference with Marchia's self-expending impetus had no real natural philosophical consequences, since Buridan assumed that all earthly bodies have an intrinsic tendency towards rest, which will gradually destroy the impetus and cause all violent motion to come to an end (see especially [12, pp.89-95]). Just as Marchia, Buridan also appealed to impetus in treating celestial motion, and he added acceleration as a further phenomenon that could be explained by it [4, pp.524-525]. In the latter case impetus is not only the cause but also the effect of motion, as Buridan assumed that the body gradually acquires more impetus as it falls. Buridan's direct successors, Nicole Oresme (1320-1382), Albert of Saxony (1320-1390) and Marsilius of Inghen (1340-1396), further took up the concept and offered treatments that afterwards spread over Europe from Paris [11, pp.100-153], [13, pp.136-137].

### 3 Innovation

#### Impetus as Aristotelian Doctrine

The sixteenth century saw an increased attention to the concept of impetus after a relative stagnation in the preceding century. It now came to be seen as part of the proper 'Aristotelian' position, with many authors going as far as ascribing the idea to Aristotle himself [11, p.156]. They could exploit the fact that Aristotle had used the idea of impressed force, while explaining away his limitation to the medium as carrier of the force (see [11, pp.156-164] for examples, including Domingo de Soto and Francisco Suarez). The idea that the impetus was present both in the medium and the projectile, a position already held by Marchia, was also regularly defended by authors who did not ascribe this idea directly to Aristotle (e. g. the Coimbra commentators [11, p.163]). Notwithstanding its popularity, there were also some sixteenth century authors who denied the legitimacy of the concept of impetus, maybe most prominently the Jesuit Benedict Pereira in his *De communibus omnium rerum naturalium principiis* from 1576 [17, p.325].

Almost all authors seem to have upheld the idea that impetus was a self-expending quality, but its precise ontological status received further subtle elaborations, e. g. in the work of the professors of the Jesuit *Collegio Romano* [17]. Among the latter, the fullest exposition was given by Paulus Valla, whose characterization of impetus was summarized by William A. Wallace as "an imperfect quality after the fashion of an intensional or spiritual form, somewhat like light and color, and as such has no contrary in first act although it has a contrary in second act" [17, p.331]. The analogy with light and color was already present in Philoponus and Marchia and helped understand its peculiar ontological status as a cause of motion that is not natural but need not be directed against the object's nature either [15, p.352][21, p.93].

Thomist philosophers proposed another elaboration which consisted in the articulation of the relation between the role of gravity in natural motion and that of impetus in violent motion. Thomas had already denied that gravity was the mover of the natural motion and had claimed that it should rather be considered the instrument of the true mover, which was the generator of the body [18]. Similarly, one could understand the impetus as in the first place a passive instrument of the proper efficient cause, the projector (cf. de Soto in [11, p.163]). This line of thought can be seen as a rather natural development of Marchia's introduction of the impetus concept in the context of discussing the nature of instrumental causality. Suarez, who offered an elaborate classification of instruments, characterized impetus as an instrument that is neither spatially

nor causally in conjunction with its user, meaning that it operates without direct spatial contact and without the need for the user to continue exerting his force [8, pp.23-24].

### **Impetus in Anti-Aristotelian Natural Philosophy**

In the same period that impetus became to be widely seen as part of the accepted Aristotelian doctrine, it was also used as a central element in attempts at constructing an alternative anti-Aristotelian natural philosophy. The most famous examples are Benedetti's *Diversarum speculationum mathematicarum et physicarum liber* (1585) and Galileo's *De motu antiquiora* (probably written between 1589 and 1592) [5]. Both authors developed a general framework based on Archimedean hydrostatics that did away with the Aristotelian concept of lightness and stressed the absolute nature of gravity. They were also keen on pointing out that Aristotle's own 'theory' of projectile motions was defective and they stressed the need to correct him by introducing an impressed force. In this way impetus became associated with a more far-reaching attempt to rethink Aristotelean natural philosophy. Galileo's original explanation of *virtus impressa* as a *privatio gravitatis* further stressed its relation to the Archimedean framework that privileged gravity as the primary physical property of bodies. Galileo also followed Hipparchus' explanation of acceleration due to a gradual loss of an earlier impressed force. (The Latin translation of Simplicius' commentary on *De Caelo* (Venice, 1584) had made this explanation widely available, and it was also reported in Perera's *De communibus* from 1576, a work that had vast circulation in Italy [9].)

One striking difference between Benedetti's and Galileo's way of talking about impetus and that of their Aristotelian contemporaries is the almost complete disappearance of ontological subtleties. Many of the earlier discussions concerning impetus were trying to carve out an acceptable place for it within the Aristotelian framework which imposed many constraints and ensuing challenges. For these explicitly anti-Aristotelian authors, it could function in the first place as an intuitive notion that could be directly appealed to to explain a number of phenomena of motion.

## **4 Legacy**

Seventeenth century authors frequently engaged in talk about impetus, but this covered a wide array of meanings.

Galileo kept on using the term after *De motu antiquiora*, but he seemed to use it in a way that is at least noncommittal to the question whether it is a cause or only an effect of motion [10]. The tendency to transfer the term from denoting a cause to an

effect can be noticed throughout the seventeenth and into the eighteenth century [13, pp. 142-143]. This shift is connected to the development of a form of mathematical physics in the Galilean tradition in which conservation of motion became one of the crucial principles. The challenges of finding mathematical structure in empirical phenomena of motion, such as falling or projected bodies, pointed towards the fruitfulness of assuming this conservation as a basic fact of nature, which thus did not necessarily need further explanation [16].

In parallel with these developments within what was sometimes called physico-mathematics, some philosophers were also directly rethinking the ontology of motion and force. Most famous was Descartes' sparse ontology in which motion becomes a state of a body that does not need a cause for its perseverance. The questions concerning the relation between motion and force that had given rise to the inclusion of impetus within the Aristotelian framework thus received very different answers in this radical alternative [10].

Whereas an author like Galileo exploited the flexibility of the term impetus to explore different ways to establish mathematical laws of motion, and Descartes presented an alternative ontological framework in which it no longer could find a place, authors within the Aristotelian tradition kept using and rethinking the concept as developed in scholastic philosophy. Maybe the most striking case is that of the Jesuit Honoré Fabri. In response to the work of both Descartes and Galileo, he attempted to find a place for some of their new ideas within the constraints of (a very broadly construed) Aristotelian philosophy, in which he gave the concept of impetus an absolutely central place but reconceived it as a formal rather than efficient or instrumental cause of motion [7].

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