What are Aristotelian natural motions? How did post-Copernicans come to reject this concept? What is gained and what is lost in this rejection of natural motions?

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1 Thesis

I will argue that from the emancipation of Aristotelian natural motions, there is a loss of metaphysical hierarchy and bias in the conception of space (and thus cosmology), and at the same time took part in the eventual overthrowing of the Peripatetic methodology and doctrine in philosophical thinking and reasoning at the time. This leads to a freer mode of thinking for the concept of space, which helped (re)-introduce mathematical and mechanistic elements as part of a revival of the Platonic and Atomist methodology.

(**L**) (P1) There is a loss of long-standing metaphysical bias and hierarchy in the conception of space.

(P2) This meant a gain in freedom in establishing metaphysical foundations in theories of space.

(P3) A new methodology could develop (and did develop) out of this freedom.

(C) My thesis.

2 Introduction

3 Aristotelian natural motions

In Aristotle's *Physics*, natural motions were those which bodies exhibit naturally, without any "constant action of an external agent".[1] To determine natural motions, according to Aristotle, one considers the composition and proportion of the four terrestrial basic elements (earth, air, fire, and water). Each element had its own natural place to which they move with their natural motions. The heavier an element is, the closer it is to the centre of the universe, while the lighter an element is, the natural place is found closer to

[1]Cushing 1998, p. 18.

the edge of the universe (Aristotle's universe was finite). Earth's natural place is at the centre, as it is the heaviest element, so its natural motion is downwards; while for fire, it is upwards. Therefore, all terrestrial elements move in vertical, straight lines. The heavenly element, aether, had its natural motion associated with uniform circular motion, because the heavens must be eternal and perfect.

Aristotelian philosophy was endowed with ontological explanation (in comparison to Atomists' physical character or Platonists' mathematics)[2] and full of dual concepts, notably potentiality-actuality, matter-form. This is central to understand why bodies move towards their natural place. Once reached, bodies are in full actuality and remain there— while moving towards their natural place, they still have potentiality and must continue to move. In *De Caelo*, the universe is an organism, not in the literal modern sense, but as a way to explain that because all bodies have a goal (the final cause, or *telos*, one of the four Aristotelian causes) and all bodies tend towards their natural goal, there must be inherent "directional tendencies" for all matter in the universe.

4 Post-Copernican rejection of natural motions

Aristotle's metaphysics and physics posed many problems and both pre- and post-Copernican figures have extensively dissected and attempted to solve these problems. With this in mind, I can only discuss one notable argument that lead to arguably the most compelling rejection of natural motion, an argument put forth by Galileo. That is to say, what Galileo rejected was more subtle than the entire Aristotelian concept of natural motions. He wanted to challenge the dogma that a body will fall with a rate proportional to how heavy it is,[3] i.e. much earth it comprises (I use the term *weight* henceforth to denote heaviness). The argument is laid out as follows:

A lighter body m falls with velocity v, while a heavier body M falls with velocity V. The connected body $(m + M)$ falls with velocity v'. Now, here are the inequalities entailed by Aristotle's physics: $m < M$ (with respect to their weights), so $v < V$. Consider the joint body—since m contains less earth, it should retard M, thus $v < v' < V$ (conclusion A). At the same time, $(m + M) > M$, so it follows that $v < V < v'$ (conclusion B). But A and B contradict *a priori*, except in the case where $v = V = v'$ (conclusion C). However, Aristotle's physics maintained as fact that $v < V$, and as a result, Galileo's argument, a *reductio ad absurdum*, shows that one must refute Aristotle's statement stated above via sound mathematical deduction.[4]

Consequently, if a body's heaviness (W) does not affect the degree of tendency (s) it has to reach its *telos*, then this is a result of faulty metaphysics on Aristotle's part. The variant between W and s does not exist, so a body does not fall (faster) because it has (more) earth, i.e. the addition of earth m does not result in increased rate of fall. The metaphysical implication of this refutation meant that Aristotelian natural motions and places would have to be given up.

[2]Jammer 1954, p. 69.

[3]Cushing 1998, p. 81.

[4]Ibid., p. 82.

While this argument is compelling on its own, Galileo, influenced by "impetus theory" of Philoponus, also developed a system to describe the kinematics of projectile motion that also stripped away the *organismic* element in which natural motions found its roots, and furthered the necessity to move away from this Aristotelian doctrine. I cannot go into depth, but consulting the critique from Philoponus alone; the cause of natural motion is found not within space, but by the agent to the body, and thus inherent in the moving body (which "shows a remarkable resemblance to the gravity suggested by Copernicus"[5]). EXPAND THIS?

The acceptance of the arguments above meant the immediate loss of authority in Peripatetic doctrine. For not only was his physics challenged, but his metaphysics has been brought under scrutiny; how can the role of *telos* be emphasised if matter, being composed by smaller earth elements which all individually express the urge to seek its natural place, no longer varies with the rate taken to reach its goal? Many before him took his philosophy as dogma, and it took many attempts to overthrow this long-standing tradition which brought along with it deep metaphysical bias and hierarchy. This break in tradition is clearly seen by the theories which came after; the reintroduction of Platonic emphasis on more rigorous mathematics in Galilean, Keplerian, Cartesian, Newtonian, Leibnizian natural philosophy and metaphysics, alongside the many Italian Renaissance scholars who influenced these figures. While certain traces of Aristotelian thought remain in the theories expounded by these contemporaries, for example, the unchallenged survival of uniform circular orbits in Copernican[6] and Galilean cosmology (and Cartesian vortices), the sweeping ontological principles and distinctive elements Aristotle put forth as part of his metaphysics and physics were no longer upheld as dogma. Again, consider cosmological models. If the sun was considered as a ball of fire, and any contemporary of Aristotle, say Newton, who published their sun-centred world system without the burden to explain why a heavenly body, let alone one considered a ball of fire, could be placed at the centre of the universe, then such a burden to stay faithful to Aristotle did not exist. I hope to have shown that there is a loss of Peripatetic authority as a partial result of natural motions (and its metaphysical ontology) being refuted.

5 A shift in methodology

I shall argue now that by rejecting its metaphysical grounding, the departure of natural motions meant space is now open to new physical and metaphysical foundations, and a gain in more solid methodology was needed for such tasks, and indeed such a gain was observed. However, I wish to exercise my attempt carefully as to avoid sweeping generalisations. First, this gain in new methodology is not the same as but definitely affected by the loss of long-standing bias and hierarchy in the conception of space which stemmed from Aristotelian metaphysics demonstrated in Section 4. The reason why these are not the same arises from the fact that not long before the modern physics we know of today, science and theology were intertwined (even Newton's conception of space was his only religiously-biased one), therefore any figure post-Copernican who proposed new

[5]Jammer 1954, p. 57.
[6]Kuhn 1957, p. 148.

physical theories in place of natural motions will replace its metaphysical groundings with something else. Now, whether this "something else" shows a different methodological practice (and a more effective one) usually comes unjustly with the unavoidable input of hindsight. Rather, it is a careful analysis of historical records at the time which can only decide whether signs of modern scientific methodology were shown (indeed, even this requires some form of hindsight). Let me explain using cosmological world systems as an example.

Aristotle viewed space and matter as inextricably linked, since natural places differ by virtue of the basic elements, so earth, being the heaviest, found its natural place at the centre of the universe, and the natural motions of the terrestrial elements took place within the first sphere, the sublunary region. Beyond this lied the celestial sphere, the planets and stars were considered heavenly bodies, their element being aether, and their orbits around earth uniform and circular. Mathematicians whose constructions stayed faithfully close to this Aristotelian two-sphere model had to employ many workarounds in order to fit observational data. These workarounds are called *ad hoc* devices, a pejorative term given to parts of a model introduced in order to fit observational data.[7]

Consider the Ptolemaic world system: it was observed that planets occasional orbit backwards before returning to their usual direction (retrograde motion), and that they appear to vary in brightness. To explain away these troublesome phenomena, Ptolemy introduced epicycles (smaller circles which travel in a bigger circle) to account for retrograde motion, the eccentric (the centre of the bigger circle) and the equant (the point of reference wherein the epicycles appear uniform).[8] Copernicus, while known for setting the stage for the heliocentric model (sun-centred) again after previous dismissals, also employed just as many circles as Ptolemy did,[9] and while there were fewer *ad hoc* devices at play, on the criterion of economy and simplicity, it was not a much better construction than Ptolemy's. Copernicus still modeled his theory to fit observational data,[10] and any data taken were not very accurate either, and as mentioned in Section 4, his (and Galileo's) theory also retained Aristotelian circular motion. At the time, on unbiased ground, it was difficult to decide between the two rivalling models, due to observations being limited to the naked eye, to see whether such a construction *really* explains the actual motion of bodies. The discrimination against the Copernican model stemmed from earth-centred bias of authority at the time which still held onto its Aristotelian doctrines. Therefore, to completely remain unbiased to the hindsight of scientific modernity, any model which, no matter how close it is to the present accepted theory, cannot show stronger methodological background if it was arrived at with *ad hoc* devices.

On the other hand, a new methodology was recorded. The invention of the telescope lead Galileo to make observations which showed many problems with the Ptolemaic model. As well as not showing bias for a Copernican model,[11] he argued with evidence and clear reasoning why such a model should be preferred. Merits were to be given to

[7]Cushing 1998, p. 22.
[8]Ibid., p. 51.
[9]Ibid., p. 65.
[10]Ibid., p. 67.
[11]Ibid., p. 142.

Galileo, who argued for the "superiority of reason and observation"[12] and demonstrated a methodology different to those who came before him. Note that as part of the series of arguments against Aristotelian straight natural motion, experiments with objects rolling down inclined planes were performed and the method detailed. Kepler, equipped with Brahe's data, also arrived at his First Law, where bodies now travel on elliptical paths, and this signified the death of all Aristotelian natural motions. Therefore, with historical evidence, I put forth my claim that new theories of motion and space proposed in place of Aristotle's natural motions and places lead to a different and better methodology.

6 Conclusion

References

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[12] Cushing 1998, p. 141.