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?

1 Introduction

In this essay, I will start by explaining the Aristotelian concept of natural motions, and then provide arguments on how one of the post-Copernican scholars, Galileo, rejected this notion. I will then argue that resulting from the emancipation of natural motions are (1) a loss in the role metaphysical purpose in theories of nature, pertaining to the space, motion and cosmology, and (2) a gain in a significant shift in philosophical methodology away from self-evident axiomatic reasoning to quantitative and mathematical investigation.

2 Aristotelian natural motions

In Aristotle's *Physics*, natural motions were those exhibited by bodies without the need of "constant action of an external agent".[1] In fact, the concept of natural motions perhaps defined what it means to be one of the four terrestrial basic elements (earth, water, air, and fire, in ascending order by weight).[2] To start, each element had its own natural place to which they move with their natural motions. The heavier an element is, the more it travels downwards, so it is found close to the centre of the universe, while the lighter an element is, the more it travels upwards, and we find it closer to the edge of the universe (Aristotle's universe was finite). Earth's natural place is at the centre, as it is the heaviest element; while fire moves upwards. Therefore, all terrestrial elements move in vertical, straight lines. The heavenly element, aether or quintessence, had its natural motion associated with uniform circular motion, because the heavens must be eternal and perfect.

[1] Cushing 1998, p. 18.
[2] Barbour 1989, p. 75.

Aristotelian philosophy came with inextricable metaphysical foundation (in comparison to the emphasis on physical character by Atomists or mathematics by Platonists)[3] 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. As an aside, we might be able to appreciate how this anticipated the modern concepts of potential energy and actual, or kinetic energy. What is no longer seen in modernity, however, is this doctrine in Aristotle's *De Caelo*: the universe as an organism, not in the literal animalistic sense, but as a way to explain that because all bodies have a goal (the final cause, or *telos*, one of the Aristotle's four causes, the rest being material, formal and efficient) and all bodies tend towards their natural goal, there must be inherent "directional tendencies" for all matter in the universe.

3 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 led 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,[4] 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.[5]

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

[3]Jammer 1954, p. 69.
[4]Cushing 1998, p. 81.
[5]Ibid., p. 82.

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.

While this argument is compelling on its own, natural motions also struggled to explain forced motion (those acted on externally), and Aristotle used what is known pejoratively as an *ad hoc* device to explain away why an arrow might keep moving horizontally after it has left the archer's bow. In essence, the organic nature of space meant the objects comprising the medium in which a body moves through with forced motion somehow 'closes in' at the back of the projectile to keep it along its path. In response, Philoponus posed: why can't we displace object by pushing the air around and behind it? The mitigation was to propose instead that the cause of natural motion is found not within space, but by the agent to imparting some 'force' to the body, and thus remains in the moving body (which "shows a remarkable resemblance to the gravity suggested by Copernicus"[6][7]). Galileo, influenced by this "impetus theory" of Philoponus, went on to develop a system which describe the kinematics of projectile motion in a completely mechanistic manner. It also explains well why the path of projectiles is parabolic and not circular, as previously assumed. This construction completely stripped away the *organismic* element in which natural motions found its roots, and furthered the necessity to reject and move away from this Aristotelian doctrine.

4 Losses

By accepting this rejection, the entire body of Aristotelian metaphysical doctrine could be brought under scrutiny. Those who held onto the shaky foundations of his theories did so not out of philosophical justification but was a matter of theological power struggle. While not all Aristotelian concepts were flawed, and some, if further developed, might have achieved what was communicated much later in the scientific revolution,[8] there were two conflicting mechanism at play: either towards teleology (explanation as a function of purposes or ends) and theology, or towards careful quantitative experimentation.[9] Theological climate at the time meant the former was "intimately entangled" with astronomy. The upshot of this meant the former direction was preferred, and led to the ridiculing of 'heretical' models of nature.[10] Nevertheless, with this rejection, what was challenged was not only a long-standing theological dogma, but also the metaphysical emphasis

[6]Jammer 1954, p. 57.
[7]Cushing 1998, p. 156.
[8]Barbour 1989, p. 77.
[9]Ibid.
[10]Kuhn 1957, p. 86.

on *telos*. I shall argue for this loss which resulted from the rejection of natural motions.

First, 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? If mechanistic and mathematical relations can describe the motion of a projectile, in the case of Galileo, or the world-system, in the case of heliocentric overturn of natural places, better than Aristotle's theories, then where is the causal role of *telos* in nature? Although theistic and mystic elements have yet to leave natural philosophy (even Newton's conception of space was religiously motivated, as he was influenced by religious elements in More's philosophy[11][12]) until the logical positivist revolution took over the domains of natural philosophy (the view that statements can only have meaning if they can be demonstrated through direct observation or logical proof), *telos* as a final cause did not find itself revived in the post-Copernican theories and signified the eventual death of a spatial "hierarchy of values".[13] Take Galilean invariance—physical laws are unchanged in two systems with relative motion between each other, this would seem to imply that the degree of *telos* is changed under a simple Galilean transformation between frames of reference. Consider a barrel next to me, both on a moving ship, would appear stationary in my frame (it has reached its natural place), but indeed is moving at the ship's speed with respect to the waves (which might have some vertical motion), and the waves at some relative speed with respect to the earth (which moves in a complex manner, a combination of both vertical and horizontal), so on and so forth. So with each subsequent transformation, the rate at which the barrel travels to the centre of the universe is different, implying either that its matter has to be changing (which is not), or that its *telos* is. As the final cause, however, *telos* ultimately emenates from the Prime Mover, which is the teleological divine entity responsible for world order. The Prime Mover is absolutely actual and never potential, thus cannot change.

What's more, even though Leibniz came the closest to the Aristotelian concept of hylomorphism (duality of matter and form) by imbuing material bodies with *vis viva*—the quantity mv^2 known otherwise as living force—even such a quantity is to be determined from another mechanistic quantity: velocity squared (mass m here is left open for interpretation; Leibniz's monadic philosophy will not be discussed here, but it was likened to Atomism[14] rather than Aristotelianism or Scholasticism). The causal nature of *telos* was nowhere to be found. For many of these theories, there was a shift in nature, from being organismic to being

[11]Cushing 1998, p. 157.
[12]Jammer 1954, p. 113.
[13]Ibid., pp. 82–3.
[14]Ibid., p. 64.

mechanistic,[15] and the four causes collapsed to just one efficient cause. While it is possible to provide more accounts of new, non-Aristotelian metaphysical foundations, I hope this is ample evidence to show that the concept of *telos* was buried alongside natural motions.

5 Gains

Complementary to this loss was the slow shift towards the other direction in the development of natural philosophy. Whereas the medieval philosophers prioritised metaphysical foundation to appease to religious orthodoxy, the rejection of natural motions was arrived at with increasing preference towards "quantitative investigation",[16] notwithstanding rigorous mathematical and logical argumentation. While mathematical constructions appeared under the Peripatetic authority, they were ridden with problems that would only be covered up by the use *ad hoc* devices. An example is seen with the complicated Aristotelian-Ptolemaic geocentric world-system of off-centred orbits and circles-within-circles. Even when it was not common for some Aristotelian thinking to remain until some creative input broke free of the old tradition, as seen with uniform circular motion as the natural motion of planets in Copernican, Galilean and Cartesian physics (Kepler's First Law about elliptical orbits of bodies around the sun which finally put an end to the circle), many figures drifted away from axiomatic investigation (emphasis on "self-evident" axioms and "cursory" observation[17]) and onto inductive (generalisations from more careful observations) and retroductive (going from theories to hypotheses or predictions that are validated or falsified with further observations) investigation.[18] Let me provide further evidence.

The invention of the telescope meant Galileo made observations which showed many problems with the Ptolemaic geocentric model, as well as lunar craters and sunspots, which were direct conflicts to Aristotelian order and symmetry. At the same time, this meant "countless evidence" for the Copernican heliocentric model.[19] While Galileo did not show bias for a Copernicanism,[20] he argued with evidence and clear reasoning why such a model should be preferred. Merits were to be given to Galileo, who supported the "superiority of reason and observation".[21] If a theory does not correspond with observation, it does not suggest the use of arbitrary *ad hoc* solutions, but perhaps the abandonment of the theory

[15] Cushing 1998, p. 19.
[16] Barbour 1989, p. 77.
[17] Cushing 1998, p. 34.
[18] Ibid., p. 35.
[19] Kuhn 1957, p. 219.
[20] Cushing 1998, p. 142.
[21] Ibid., p. 141.

itself, especially if it carries metaphysical bias. What's more, as part of the series of arguments against Aristotelian straight natural motion, experiments with objects rolling down inclined planes were performed and a mathematical relation was arrived at—$v \propto t^2$ (as opposed to $v \propto m$), as well as those for projectile motions mentioned above. While innovative theories such as Galileo's (and Kepler's, not mentioned here) were not purported without opposition, their eventual assimilation meant gain in a new priority in philosophical investigation; not in ontological origins, but in careful quantitative observation and experimentation.

6 Conclusion

I have answered the question by explaining the concept of natural motions, which were the defining properties for matter in the form of the basic elements, then argued how this was rejected from two Galilean arguments. From the abandonment of this concept, I argued that this resulted in the loss of the Aristotelian doctrine of endowing space with metaphysical *telos* notwithstanding the overturning of Peripatetic dogmatic way of thinking. At the same time, this also paved way to newer methodology, which placed less emphasis on metaphysics and theology, while involving more rigorous quantitative investigation and experimentation, as well as regarding strong mathematical and logical reasoning as championing over metaphysical foundations.

References

Barbour, J. B. (1989). *The Discovery of Dynamics: A Study From a Machian Point of View of the Discovery and the Structure of Dynamical Theories*. Cambridge, England: Oxford University Press USA.

Cushing, J. T. (1998). *Philosophical Concepts in Physics: The Historical Relation Between Philosophy and Scientific Theories*. Cambridge University Press.

Jammer, M. (1954). *Concepts of Space: The History of Theories of Space in Physics*. Cambridge: Mass., Harvard University Press.

Kuhn, T. (1957). *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought*. Harvard University Press.