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thesis

From Celestial Commentaries to Medieval Dynamics.

What theories of sublunar dynamics arose from John Philoponus' attacks on Aristotle's theory of the aether, and what influence did these theories have on the development of medieval and early modern physics?

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Table of Contents:

Introduction.....	3
The Aristotelian commentators.....	7
The commentating tradition.....	7
Influences and works	7
The metaphysics of the commentators.....	10
Celestial theories compared	16
The aether and its properties.....	16
The development of Philoponus' theories of motion.....	21
Theories of terrestrial and celestial dynamics.....	21
Philoponus' changing notions of celestial dynamics.....	24
Philoponus' final theory of celestial motion.....	28
Influence of Philoponus on medieval dynamics	32
Early medieval ideas of motion.....	32
Validity of historiographical arguments concerning Philoponus' influence	33
Conclusion	41
Bibliography	44

Introduction

Richard Sorabji CBE FBA, Emeritus Professor of Philosophy at King's College London: 'The Philosophy of the Commentators of 200-600CE constitutes the transition from Ancient to Medieval Philosophy'¹

As Sorabji explained in 1990, the scientific legacy handed on from the Ancient world to the Middle Ages was not merely Aristotelian but 'a far richer compilation transformed by the preoccupations of the intervening commentators.'² But the critical importance of the commentating tradition has only recently been examined with due appreciation by historians of science. In 1978 the historian of medieval science Edward Grant, effectively minimising the influence of the commentators, argued that the general longevity of Aristotelian cosmic mechanics was a function of the diversity and apparent inconsistency of its challengers.³ In his 1994 work *Planets, Stars and Orbs* he repeated this opinion, noting that challenges to the dominant world view appeared incapable of replacing the tightly integrated system of Aristotelian cosmology that had gained such dominance despite serious anomalies of its own.⁴

Focusing specifically on the Aristotelian theory of the fifth element – the *quintessence*, or aether – Christian Wildberg (writing in 1988) agreed with the explanandum but not the explanans of Grant's thesis. Wildberg argued that the theory's enduring acceptance could be explained not by a lack of challenge to the Aristotelian framework (for he showed that there was at least one significant challenge) but to the enduring plausibility of Aristotle's theory of motion in the sublunary sphere, a natural consequence of which involved the hypothesis of a body in the celestial sphere that is necessarily endowed with motive and sensible qualities different in kind from the four elements comprising the terrestrial domain.⁵ Wildberg additionally maintained that the authority of Aristotle's argument for the existence of

¹ Sorabji (ed.) (2004), p1

² Sorabji (1990b), p198

³ Grant (1978), p95

⁴ Grant (1994), p678

⁵ Wildberg (1988), pp99-100

the aether had been fortified by Aristotelian commentators, church theologians and scholastic philosophers for over 2,000 years from its first elaboration in the 4th century BCE, such defence having been raised in spite of considerable philosophical failings in Aristotle's theory, failings that had been debated by (amongst others) John Philoponus (490 to 570CE), a Christian philosopher, scientist and theologian, and his Neoplatonist philosophical opponent Simplicius (c.490-c.560CE). But Wildberg also advanced a significantly more radical argument that innovative ideas first articulated by Philoponus may have provided Arabic commentators – and through them medieval Latin Europe – with the beginnings of ideas on the dynamic movement of bodies that might lead to the modern notion of inertia as applied to celestial bodies.⁶

Philoponus is the main character in this discussion but relevant arguments from other Aristotelian commentators (particularly Simplicius) make an appearance from time to time. English translations of the extant body of their work and that of other late-Hellenistic commentators have only relatively recently become available through the collaborative international translation effort – the 'Ancient Commentators on Aristotle' project – which continues under the direction of Richard Sorabji. The commentators thus represent an important but much under-studied aspect of the history of science which, alongside Arabic philosophy, represented what Lloyd P Gerson in 2005 (echoing Robert W Sharples, 1992) called part of the 'missing link' between the scientific philosophy of the ancient Greeks and that of medieval Latin Europe.^{7,8} The project seeks to present, much of it in English for the first time, the vast body of important philosophical work produced between 200CE and 600CE by the Peripatetic and Neoplatonist commentators.⁹

As late as 1990, according to Sorabji, the story of the commentators had 'not previously been told at book length'.¹⁰ Yet their importance is generally accepted – medieval Latin-speaking Europe obtained its knowledge of Aristotle (384-322BCE) at

⁶ Wildberg (1988), p5

⁷ Gerson (2005), book review in 'Bryn Mawr Classical Review',
<http://ccat.sas.upenn.edu/bmcr/2005/2005-07-55.html> - accessed 23 June 2008

⁸ Sharples (1992), p132

⁹ Sharples (1992), p132

¹⁰ Sorabji (1990), p.vii

least partly through the medium of the commentaries.¹¹ Robert Sharples, in agreement in 1992, noted that many novel scientific ideas – including a description of a form of impetus theory set out by Philoponus – represented a legacy from the Greek commentators that required to be appreciated if medieval interpretations of Aristotelian thought were to be properly understood.¹² So Sorabji's effort to produce a translation of much of their output – at about 15,000 pages, significantly greater volume than the whole of Greek philosophical original output from the pre-Socratic and early Hellenistic era – provides, for the first time in generations, important new and abundant source material to be studied by historians of ancient science.

Given the vastly improved accessibility to these works now available, I intend to examine those commentaries that specifically relate to the theory of the aether and to explore, as far as possible in a limited study, the extent to which they influenced the development of the science of dynamics in medieval Latin Europe and, later, in the beginnings of the early modern period. The choice of Aristotle's theory of the aether and its associated commentaries as the subject of this study – from all of the many available options – has not been made without some thought. *De Caelo*, in which Aristotle set out the philosophical basis and reasoning for the existence and nature of the aether, is acknowledged as 'one of the most important and influential of Aristotle's treatises', providing an intellectual basis for philosophical cosmology in the Arabic schools in the early middle ages and attracting significant commentaries from Arabic masters Avicenna (980-1037) and Averroes (1126-1198).¹³ *De Caelo* therefore provides a fitting focus for a study of the extent to which the commentators generally influenced medieval scientific thought.

My overall intention here is not only to review and criticise Wildberg's argument that Philoponus' later doctrine anticipated the application of a theory of impetus to the apparent circular movement of the heavens.¹⁴ As part of a critical analysis, I intend to assess whether Wildberg's contention remains valid in light of the extensive, newly

¹¹ Sorabji (1990a), pp24-25

¹² Sharples (1992), p133

¹³ Sorabji (2002) in Simplicius, *On Aristotle On the Heavens 1.1-4*, p9

¹⁴ Wildberg (1988), p5

accessible source material made available by Sorabji's project. But I also want to explore two broader historical questions. The first is about how scientific knowledge and theories were transmitted through the early medieval period, and the extent to which such knowledge influenced Arabic philosophers such as Avempace (d. 1139) and Avicenna, and through them medieval and early modern European philosophers including Thomas Aquinas (c.1225-1274) and Galileo (1564-1642). The second is to consider the extent to which historians of science, in their search for antecedents of modern scientific notions, seize and build upon tentative evidence to draw far-reaching conclusions; and hence the extent to which the historical soundness of those conclusions must be treated with some caution.

This study has a broad base, with an argument grounded and then advanced in five parts. It begins with a brief introduction to the tradition of the commentators and to the social, political and religious context of their work insofar as it is relevant to our understanding of their metaphysical beliefs and objectives. Next, I provide a brief review and comparison of the main ancient theories of the nature, substance and dynamics of celestial matter. This chapter will draw heavily on the evidence of the primary sources with which the commentators mainly worked – Plato's *Timaeus* and Aristotle's *De Caelo* – and from the works of the commentators themselves, mainly drawn from the new translations made available in Sorabji's project. Thirdly, I set out an account of the development of Philoponus' own theories of dynamics evident from his published works (also made available by Sorabji's project), together with a review of Wildberg's argument on how and why those theories extended from the terrestrial to the celestial realm. Fourthly, the influence of Philoponus' ideas on the Aristotelian Arabic commentators will be traced by reviewing and criticising the validity of relevant historical conclusions reached respectively by Fritz Zimmermann (1987), who agreed with Sorabji and Shlomo Pines (in a distinguished career of published scholarly work from 1938 to 1961) that the impetus theory of Medieval Latin Europe was inspired by a framework constructed by Philoponus; and Michael Wolff (1987), who denied that impetus theory provided a link between Aristotelian physics and classical mechanics. Finally, the putative influence of Philoponus' theories on later philosophers – including Bonaventure (1221-1274), Thomas Aquinas and Galileo – will be discussed on the basis of the evidence reviewed.

The Aristotelian commentators

The commentating tradition

The philosophy undertaken during late antiquity – for these purposes *c.* 200-600CE – continued conventional exegesis in the tradition of Andronicus (*fl.* 1st century BCE), the leading exponent of which was Alexander of Aphrodisias (active in the late 2nd – early 3rd century CE). Alexander, the most significant Aristotelian philosopher in Athens of the period, wrote commentaries on most of Aristotle's treatises, limiting his discussion to brief interpretive points in an effort to systematise and extract the actual thoughts of Aristotle and thus helping to establish Aristotle's philosophy as an active presence in later antiquity. Alexander's legacy for posterity was significant – Simplicius (in *In Physics*, 80.16) described Alexander as 'the most authentic interpreter of Aristotle', while the primary Catholic theologian Thomas Aquinas (1225-1274) considered him an important source of 'true Aristotelian doctrine'.¹⁵ But Alexander was the last in the tradition of pure interpreters of Aristotle. Later commentators were instead motivated by the ideal of reconciling the philosophical outlooks of Plato and Aristotle, an approach undertaken by Syrianus (*fl.* *c.* 430CE) and then through teacher-pupil relationships to Proclus (412-485CE) and thence to Ammonius (*c.* 440-520CE), who spent most of his life teaching as head of the Neoplatonist school in Alexandria. Ammonius taught – or at least lectured to – both of the main characters around whom this discussion will be built, Simplicius and Philoponus.¹⁶

Influences and works

The political and religious times of Ammonius, Simplicius and Philoponus were unsettled. The balance of power was shifting from Paganism to Christianity, although both groups drew spiritual and theological support from the dominant Neoplatonist philosophy.¹⁷ Relationships between pagan Neoplatonists and Christians were bitter in Athens but better elsewhere, with reports of accommodations between Neoplatonists and the Christian authorities allowing teaching to continue. Ammonius

¹⁵ <http://plato.stanford.edu/entries/aristotle-commentators> - accessed 14 July 2008

¹⁶ Sorabji (1983), pp200-201

¹⁷ Sorabji (1983), pp201-202

included the Christian Philoponus amongst his pupils there. In Athens however, where Simplicius was working, the Roman Emperor Justinian put a stop to Neoplatonist teaching. Simplicius, together with the head of the Athenian Academy and several others of the school, took brief refuge in Mesopotamia in the year 532CE, although there is evidence that Simplicius returned to Athens, free to write his commentaries on Aristotle after that date.¹⁸

The philosophical debate between Neoplatonists and Christians turned on the question of whether God was causally responsible for the existence of the universe and, as a separate question, whether the universe is eternal or has a beginning and an end.¹⁹ While these issues are beyond the scope of this discussion, the necessary consequences revealed by the associated philosophical arguments have a critical bearing on the question of the existence and nature of the celestial sphere, and this subject will need to be considered more carefully below. But first, for the purposes of this discussion, some of the biographical and bibliographical detail of our main characters needs to be explored.

Charles Kahn (1960) noted that Simplicius was a ‘well-read scholar’, a master of Aristotle but also influenced by other Aristotelian authors. For example, he occasionally quoted Theophrastus (371-287BCE, Aristotle’s successor as head of the Peripatetic school and complete embracer of Aristotelianism). Simplicius compiled great scholarly commentaries on Aristotelian philosophy and, influenced by his teacher Ammonius and in the tradition of the Neoplatonist commentators, worked to reconcile the different philosophies of Plato and Aristotle.^{20,21} In *In Physics*, (1249,12-17 Diels) he characterised the methodology of Plato as ‘intellectual intuitions’, while Aristotle's was based on ‘the data of perception’ (or sensation), a method for which Plato ‘frequently displays contempt’. For Simplicius, ‘demonstrative perfection’ involved both methods applied in parallel to produce a harmonious conclusion.²² It was, said Simplicius, the duty of commentator to ‘display

¹⁸ Per Hoffman (1987), p58n

¹⁹ Sorabji (1983), pp201-202

²⁰ Kahn (1960), p13

²¹ Sorabji (1983), pp199-200

²² Hoffman (1987), pp78-79

[the] harmony of Plato and Aristotle in most things' because '...the disagreement between the two philosophers does not relate to fundamentals.'²³ Thus, by implication, the more accessible Aristotelian works helped to gain insight into the 'bigger mysteries' of Plato.²⁴ Aristotle was the explanation for the *hoi polloi*, while Plato was for the intellectual – or, as Simplicius put it (*In De Caelo* 679,27-31 (Heiberg)):

'Aristotle relies on the usage accepted by the multitude which he does not want to stray from ... Plato, on the other hand, despises the usage of the multitude...'

And (*In de Caelo* 69,11-15 (Heiberg)):

'Because of his love of precision, Plato rejects the ordinary use of words, while Aristotle employs it. It is a method which he [Aristotle] thinks does no harm to the truth.'²⁵

Simplicius' surviving works include commentaries on Aristotle's *Physics* (c.532CE) and *Categories* (c.538CE). But his main work to be examined here is the commentary on *De Caelo*, a strong defence of Aristotle and a bitter counter-attack on Philoponus, written after the publication of Philoponus' *De Aeternitate Mundi contra Aristotelem* ('*Against Aristotle, on the Eternity of the World*')²⁶.

While Simplicius' story presents an unswerving devotion to the defence of Aristotelianism and the commentating tradition of reconciling Plato and Aristotle, Philoponus' story is rather more varied, at least in terms of his attitude to prevailing orthodoxy and his propensity for innovative thinking. He was educated in logic and philosophy under Ammonius in Alexandria. Wildberg considers that he may already have been a Christian when a young man, but in any event he became increasingly involved in the Monophysite controversy of his time, defending Monophysites theologically and philosophically. His religious and philosophical views respectively

²³ Simplicius *In De Caelo* 640,27-28 (Heiberg edition) in Hoffman (1987), p78

²⁴ Sharples (1992), p138, quoting Simplicius' commentary on the *Categories*, 7.23-32

²⁵ Hoffman (1987), p78

²⁶ Henceforth '*Contra Aristotelem*'.

appear to have been equally malleable. Over time (and as examined below) his empathy with the philosophy of Plato grew in proportion to his disaffection for orthodox Aristotelianism.²⁷ Even in defending his religious beliefs, he was equally unconventional – as a Tritheist member of the Monophysite sect, Philoponus was posthumously condemned as a heretic by the Church (in 680-681CE) because of his support for the Tritheistic interpretation (i.e. three separate divinities, rather than a single God in one person) of the Trinitarian dogma.²⁸ But throughout his published works in defence of his Christian belief, Philoponus sought to support his faith by the application of reason.

Wildberg asserts that Philoponus is now recognised as a ‘fascinating and remarkably independent thinker in his own right’, with modern accounts of his physical theories (including impetus theory) considered as a ‘major contribution to the transition from ancient to modern physics’.²⁹ His published output included a commentary on the *Physics* (517CE), a polemical treatise *De Aeternitate Mundi contra Proclum* (‘Against Proclus, on the Eternity of the World’)³⁰ (527CE), a commentary on the *Meteorology* (after 529CE), *Contra Aristotelem* (530-534CE) and a later work *De Opificio Mundi* (557-560CE), an exegesis of the Mosaic account of beginning of the world.^{31,32,33}

This discussion turns to the developing philosophy, over time, of our main characters. Simplicius views were unwavering in his defence of Aristotelianism. But in the case of Philoponus, his developing metaphysical basis can be traced through his works.

The metaphysics of the commentators

Philoponus and Aristotle (and therefore Simplicius, who stands in Aristotle’s shoes) differed on the eternity of the world, the existence of aether, the dichotomy of the sub-

²⁷ Wildberg (1988), pp2-4

²⁸ In discussion (on 20th August 2008), Professor Robert W. Sharples characterised the extent to which Philoponus’ was held as anathema by the orthodox Church – he was ‘regarded as a heretic even by the heretics’.

²⁹ Wildberg (1988), p1

³⁰ Henceforth ‘*Contra Proclum*’.

³¹ Wolff (1987), p119

³² Sorabji (1987), p7

³³ Wildberg (1988), p235

lunar and celestial regions, and on Aristotle's 'Prime Mover' against Philoponus' Creator-God. But there were some significant continuities also. Philoponus agreed with Aristotle that the world was spatially finite, limited by an outer sphere of fixed stars outside of which there is nothing. The earth rested at centre of the universe in a state of equilibrium surrounded by layers of water, air and fire, each of which is endowed with a natural motion: earth and water downwards, fire and air upwards to the periphery of the sublunar region.³⁴

The first metaphysical standpoint concerning the commentators' views on the mobility of the heavens related to the existence of a living force – a 'world-soul' or Aristotle's 'Prime Mover' through the perpetual agency of which the motion of the heavens is maintained. Proclus argued that the universe as a whole must have a soul on the basis of Plato's *Phaedrus* 245E: '...while a body whose motion comes from within, from itself [i.e. from the cosmos itself] does have a soul, that being the nature of a soul'. Philoponus' commentary on *the Physics* (517CE) (which appears to draw on an earlier *De Anima* commentary that may be based upon Ammonius' lecture notes) subscribes to the Neoplatonist view that celestial motions are caused by souls.³⁵

'...the main masses of the elements are unmoved. For fire does not move in its own place but stands still, for its circular movement and moreover that of the proximate air are not natural but above [their] nature, through their being carried round by the rotation of the heavenly spheres.'³⁶

He endorses a similar argument in *Contra Proclum* (527CE) although adding a natural consequence, the turning of the 'firesphere' around which the celestial bodies are embedded. But in his subsequent commentary on the *Meteorology*, Philoponus advances a radically new idea – that fire moves naturally in a circle:

³⁴ Wildberg (1988), p237

³⁵ Wolff (1987), p119

³⁶ Philoponus *In Physics* 198,12-16 in Sorabji (ed.) (2004), p353

‘...things in the celestial region generate circular motion, imitating the *nous* [cosmic intellect] to the best of their ability’.³⁷

The doctrine of the world-soul is never directly endorsed by Philoponus in *In Meteorology*. The comparison with *Contra Proclum* (which starts the same argument but introduces the world-soul as the motivating agent) is therefore fairly stark.

In *Contra Aristotelem* (530-534CE), in which he attempted to justify the Christian doctrine of *creatio ex nihilo* by subjecting Aristotle’s arguments in *De Caelo* to a searching philosophical examination, Philoponus proposed a thesis of ‘double causation’ or a joint action by natural circular motion and soul (the firesphere being turned by the nature of fire itself). As reported by Simplicius in his response to *Contra Aristotelem*:

‘Philoponus shows by means of many arguments which, as he says, are in agreement with Plato, that the circular movement of the heavens is natural and imparted by a soul because the heavens are a living being.’³⁸

In his response, Simplicius sought to refute Philoponus’ arguments contained in *Contra Aristotelem*. He reaffirmed ‘the divinity, the transcendency, and the eternal nature of the heavens’. Simplicius again aimed to connect rather than contrast Aristotle’s *De Caelo* and Plato’s *Timaeus*.³⁹ According to Philippe Hoffman (1987), Simplicius’ attack on Philoponus’ *Contra Aristotelem* was a form of prayer; ‘The sacrilegious blasphemy of the Christian Philoponus is countered by the Neoplatonist liturgy, a rightful celebration of their God’. Hoffman sees it as a necessary process of purification undertaken by Simplicius before his readers can undergo the ‘revelation’ of initiation into ‘the grandeur of the universe and of the heavens’.⁴⁰

Philoponus has separated the firesphere from the celestial body and movement of the first does not explain movement of the second – hence the need for another principle,

³⁷ Philoponus, *In Meteorology*, 339a24-27 from Wildberg (1988), p240

³⁸ Simplicius *In De Caelo* 78,17-22 in Sorabji (ed.) (2004), p345

³⁹ Hoffman (1987), p57

⁴⁰ Hoffman (1987), pp57-58

the supernatural agent.⁴¹ Wildberg regards this as unsatisfactory and I agree; I suggest that this highly uneconomical solution is proposed only because of the overwhelming requirement to conform to the authority of Plato at that time. But even this responsibility is abandoned as his gradual departure from the ontological validity of the world-soul is confirmed in his last major treatise, *De Opificio Mundi* (557-560CE), a serious attempt to reconcile Christian belief with Aristotelian and Platonistic philosophy written 20-30 years after *Contra Aristotelem*.⁴² The existence of a world-soul is rejected in favour of universally imparted forces.⁴³ Philoponus' new idea is clear (*De Opificio Mundi* 6.2, 231,3-233,8):

‘...that there is no evidence, nor testimony of the Holy Scripture, capable of showing that celestial things are ensouled.’⁴⁴

Wildberg proposed two plausible reasons that may have prompted Philoponus' change of view. Firstly, there is no argument to support existence of a world-soul; celestial bodies show no sign of 'psychical' activity other than circular movement. Secondly, Mosaic Genesis does not speak of heavens created with a soul.⁴⁵

Papyrologist Leslie MacCoull suggested in 2005 that Philoponus' underlying approach to science is better understood by considering his social background as an objector to Chalcedonian church orthodoxy. *De Opificio Mundi*, explains MacCoull, is best seen as a Miaphysite⁴⁶ commentary on Genesis, reconciling the available data and theories of classical science with those of Christian revelation. Philoponus had extended his earlier work in an effort to create a grand theory of the created universe

⁴¹ Wildberg (1988), p162

⁴² Wildberg (1988), pp2-4

⁴³ Wildberg (1988), pp163-165 and p236

⁴⁴ Sorabji (ed.) (2004), p347

⁴⁵ Wildberg (1988), p241

⁴⁶ 'Miaphysitism' (historically considered by the western orthodox churches as a form of Monophysitism) is the Christology of the Oriental Orthodox churches that holds that the two natures of Divinity and Humanity are united in the single nature of Christ.

wholly integrated with biblical interpretation as comprehended by of 6th century non-Chalcedonian Christians in Egypt.⁴⁷

While considering the metaphysical basis of Philoponus' approach to science, it is appropriate to consider another apparent desideratum that he applied to his scientific thinking – that of parsimony of explanation. In his consideration of the Aristotelian substrate 'prime matter' for example, Philoponus accepted in his *Physics* commentary the conventional view that length, breadth and depth were quantities imposed on prime matter and not themselves substances.⁴⁸ But in *Contra Proclum* he had new idea: to treat 3-dimensional extension as ultimate subject of bodies, dispensing with the lower-level subject found in Aristotle. This removes, at a stroke, a puzzle that troubled philosophers attempting to describe the essential qualities of pure matter for millennia – even John Locke (1690) gave up on the matter, characterising the answer is that which would given by children – 'That it is *something* ... but that they know not what.'⁴⁹ As Sorabji describes, Philoponus' idea presents certain difficulties, but these are rather beyond the scope of this discussion. The critical point is the evidence this provides of Philoponus' *modus operandi* as a seeker of parsimonious scientific explanations.⁵⁰

These two aspects of Philoponus taken together – his background as staunch proponent of Monophysite faith together with a desire for efficiency of scientific explanation – are important elements of this discussion that will be reconsidered with later evidence. For now, however, these subjects bring us back Simplicius, who (from the invective delivered in his response to *Contra Aristotelem*) clearly found Philoponus' religious tendencies and deficiencies as an Aristotelian commentator profoundly irritating. Wolff suggests that Simplicius regarded Philoponus not as an exponent of Aristotle but of 'Egyptian Mythology'.⁵¹ Simplicius was quite unequivocal concerning the characteristics of a satisfactory interpreter of Aristotle – he set them out in the prologue to his commentary on the *Categories*. A 'good'

⁴⁷ MacCoull (2005), pp397-423

⁴⁸ Aristotle, *Metaphysics* 7.3, 1029a12-15 in Barnes (ed.) (1995), p1625

⁴⁹ Locke, J. (1706), p191

⁵⁰ Sorabji (1987), pp18-23

⁵¹ Wolff (1987), p106 – although Wolff's source for this precise expression is not clear.

interpreter must have sufficient (i.e. considerable) intellectual acuteness to be capable of grasping Aristotelian ideas. He must be familiar with the whole Aristotelian corpus and Aristotle's linguistic peculiarities, he must apply his intellectual judgment with honesty and integrity, and (primarily) must identify the harmonies between Plato and Aristotle by distinguishing between the letter and the spirit of the texts, the latter of which will tend to agree. Hoffman considered, given Simplicius wrote this after *In De Caelo* and *In Physics*, whether this list of qualities was produced in order to make a point about Philoponus, whom Simplicius accuses elsewhere of falling short in all of these essential qualities.⁵²

We are left therefore with a view of Philoponus as an innovative thinker, a seeker for simple, effective and reasoned reconciliation between his knowledge of the natural world and his Christian faith. Simplicius, less original in philosophical output perhaps, represented his pagan religious beliefs and his view of the sacred nature of Plato's and Aristotle's works with no less passion. It is to the detailed arguments of the main participants in this discussion on the question of the nature and motion of the heavens that I now turn.

⁵² Hoffman (1987), pp59-60

Celestial theories compared

The intention in this section of the discussion is to examine the arguments set out by Aristotle together with Philoponus' response on the question of the nature of the celestial sphere and the motions of the heavenly bodies. Some additional commentary from other commentators is also considered insofar as they provide critical insight into our understanding of one side or the other.

The aether and its properties

An explanation of the cosmos based on a geocentric system, contrasting between an inferior terrestrial region and the superior heavens can be traced in Greek thought from (almost) the very beginning.⁵³ Wildberg claimed, and it is accepted here, that the 'fundamental dichotomy of the celestial and sublunary region in Aristotle's universe' is a more-or-less automatic inference to be drawn from the generic differences observable between the terrestrial world of up-and-down movements and the unceasing, apparently endless circular movements of the stars and planets.⁵⁴ Plato (c.428-348BCE) postulated in *Timaeus* that the cosmos was comprised of four elements – earth, water, air, and fire.⁵⁵ After describing how the terrestrial elements must be composed of four of the regular solids that can be constructed from specific triangles, Plato describes a fifth:

'One other construction, a fifth [the dodecahedron], still remained, and this one the god used for the whole universe, embroidering figures on it.'⁵⁶

The heavens were made by the Demiurge (the ultimate craftsman) mainly from divine aspects of the fiery element:

'The gods he made mainly out of fire, to be the brightest and fairest to the eye. He made them well-rounded, to resemble the universe, and

⁵³ Professor Robert W Sharples – in correspondence (August 2008)

⁵⁴ Wildberg (1988), p47

⁵⁵ Plato, *Timaeus* 32B in Cooper (ed.) (1997), p1237

⁵⁶ Plato, *Timaeus* 55C in Cooper (ed.) 1997, p1258

placed them in the wisdom of the dominant circle [i.e. the celestial sphere] to follow the course of the universe.’⁵⁷

Finally, Plato argued that nothing is visible that does not contain fire, inferring that the heavens must also consist mainly of fire.⁵⁸

Plato’s pupil Aristotle introduced modifications to some of these theories, and repudiated others. But before turning to Aristotle, it is important to note that there were other theories of sublunary movement competing with those of Plato and his pupil – for example, the Stoics taught that all the elements tend towards the centre of the universe, but earth most, fire least:

‘Both Strato and Epicurus ...were of this opinion, thinking all body has weight and is carried towards the middle and because the heavier lie beneath, the less heavy are squeezed out forcibly upward by them.’⁵⁹

And, later, some members Aristotle's own school rejected Aristotle's theory of the aether, preferring Plato's view that the heavens are made of fire, for example Xenarchus, the 1st century BCE peripatetic who returned to Plato’s view:

‘...one might without absurdity assign circular motion to fire, and rest to the other three.’⁶⁰

As far as the commentators were concerned however, the Platonism of late antiquity had together with Aristotelianism had gained the upper ground in providing an adequate account of the sensible world.⁶¹

Our focus returns, for this reason, to Aristotle who regarded the observable differences in the character of motion as the fundamental aspect by which the terrestrial and celestial regions could be differentiated. In the terrestrial world, the natural movement of the elements was rectilinear, either downwards (earth and water)

⁵⁷ Plato, *Timaeus* 40A in Cooper (ed.) (1997), p1243

⁵⁸ Plato, *Timaeus* 31B in Cooper (ed.) (1997), p1237

⁵⁹ Simplicius, *In De Caelo* 267,29-268,4 in Sorabji (ed.) (2004), p329

⁶⁰ Xenarchus quoted by Simplicius in *In De Caelo* 22,16-17

⁶¹ Professor Robert W Sharples – in correspondence (August 2008)

or upwards (air and fire). Making the assumption that the natural motion of simple bodies is an aspect of their fundamental nature, he argued from analogy that if simple bodies have simple motions in the terrestrial sphere, then the celestial sphere must possess a simple motion also. Furthermore, this simple motion – circularity – can be perceived and thus the celestial sphere must be regarded as more perfect and divine, because of the axiological priority of the circle (unceasing and endless) over rectilinear motion.⁶² From this it follows that the celestial body – or the aether – has certain characteristics. First, it has no inclination to move towards or away from the centre of the earth, thus it is devoid of any nature of weightiness or lightness.⁶³ Second, as motion in a circle has no opposite or contrary (as a circle is complete and never-ending), the aether must be endlessly incorruptible and unchanging with no beginning and no end.⁶⁴

The Neoplatonist commentators made solid attempts, as expected, to reconcile the positions of Aristotle with Plato on the substance of the heavens. Proclus, for example, equated Plato's fifth regular solid – the dodecahedron to which Plato assigned to the external structure of the universe – to Aristotle's aether:

‘So the heaven is made of a fifth substance other than these four which are mixed together out of the simple [elements]. For what is in the heaven is not these, but their supreme grades and the four unmixed elements of all things which we separated from each other with their distinctive characters... And this is in very close agreement with Plato, who affirms that the heaven is composed of the four elements... but a little later assembles the five shapes and calls them five *cosmoi*, for these give a fifth substance to the heavens...’⁶⁵

...and again:

⁶² Wildberg (1988), p57ff.

⁶³ Aristotle, *De Caelo* 270a12-35 in Barnes (ed.) (1984), p450

⁶⁴ Aristotle, *De Caelo* 269b18-270a12 in Barnes (ed.) (1984), p449

⁶⁵ Proclus, *In Timaeus* 2.49,25-50,12 in Sorabji (ed.) (2004), p365

‘...For what is the difference between calling it a fifth element or, as Plato called it, a fifth cosmos and fifth shape?’⁶⁶

Simplicius was in contented agreement:

‘And so the dodecahedron was according to him [Plato] the shape of a simple body, namely that of the heaven, which he [Aristotle] called aether’⁶⁷

But Philoponus would have none of this. *Contra Aristotelem* focuses on Aristotle's cosmology and in particular the theory of the aether. Citing Aristotle's arguments in *De Caelo* and attempting to refute them systematically, Philoponus took issue (correctly in Wildberg's view) with Aristotle's axiom that simple bodies and simple motions must be in one-to-one correspondence with each other. If nature is the principle of elementary motion, and if there are five distinct elements but only three simple motions, then it is evident that different natures are able to cause the same motions. Therefore it is not possible, he asserted, to acquire knowledge of the nature of a body simply from the form of its motion.⁶⁸

Next, Philoponus sought to remove the ontological barrier between terrestrial and the celestial spheres. Simplicius found this profoundly shocking to the point of blasphemy.⁶⁹

‘...he openly proclaims that the things in the heaven do not [possess] any other nature than the elements in this world. “For there is”, he [Philoponus] says, “perhaps no quality observed in the things there that does not also belong to the terrestrial bodies.”’⁷⁰

Wildberg took impressive and meticulous pains to examine the philosophical basis of Aristotle's arguments which he deconstructs at length, syllogism by syllogism, to find

⁶⁶ Proclus, *In Timaeus* 1.6,29-7,2 in Sorabji (ed.) (2004), p365

⁶⁷ Simplicius, *In de Caelo* 12,26-27

⁶⁸ Wildberg (1988), p109

⁶⁹ Sorabji (ed.) (2004), p364

⁷⁰ Philoponus, *Contra Aristotelem* reported in Simplicius, *In de Caelo* 88,28-34

many wanting.⁷¹ Wildberg considered that Philoponus had succeeded in showing that the movement of a body does not supply sufficient information for the determination of its nature yet failed to show that the celestial body can be regarded as the same kind of substance of the sub-lunar bodies.⁷² But in the end, he plausibly concluded that Aristotle's final arguments on the eternal, unalterable quality of the aether were based on popular beliefs, astronomy and etymology.⁷³ For the purposes of this discussion however, the focus remains on the dynamical theories constructed on the basis of the various theories of the aether.

thesis

⁷¹ Wildberg (1988), p73ff

⁷² Wildberg (1988), p117

⁷³ Wildberg (1988), p88

The development of Philoponus' theories of motion

Theories of terrestrial and celestial dynamics

The Aristotelian idea of motion was built on the framework of a motionless earth and the idea that ‘everything that is in motion must be moved by something’.⁷⁴ This led immediately to a problem for Aristotle, for he then needed to explain that what keeps a projectile moving in air is an enduring force applied to the object as it underwent ‘forced’ motion (i.e. not rectilinearly vertical). Where did this enduring force come from? Aristotle’s explanation was not one of his most convincing:

‘For air is both light and heavy, and thus *qua* light produces upward motion, being propelled and set in motion by the force, and *qua* heavy produces a downward motion. In either case the force transmits the movement to the body by first, as it were, tying it up in the air. That is why a body moved by constraint continues to move even when that which gave the impulse ceases to accompany it.’⁷⁵

In other words, what kept a stone moving in the medium of air was the air itself, pushed aside by the projectile and pushing the projectile along in its turn.

From his first significant scientific work (*In Physics*, 517CE) Philoponus ridiculed the function and role assigned by Aristotle to the external medium as a necessary cause of continuing motion in projectiles, suggesting instead an incorporeal, impressed and persisting force – a ‘kinetic power’, as explained by Philoponus (*In Physics* 641,13-642,20):

‘When one throws a stone by force, is it by pushing the air behind the stone that he forces the stone into unnatural motion? Or does the man who pushes transmit some kinetic power (*dunamis kinêtikê*) to the stone itself? ... It would have been possible... to stand [an] arrow, for example, on the tip of a stick... and with ten thousand machines to set a great quantity of air in motion, and the greater the force, it ought to...

⁷⁴ Aristotle *Physics* 7.1, 241b34 in Barnes (ed.) (1995) p407 (echoing Plato, *Timaeus* 57E)

⁷⁵ Aristotle, *De Caelo* 3.2, 301b22-28 in Barnes (ed.) (1995), p494

shoot it further. But in fact... the arrow would not move even the distance of a cubit. It is clear that it is not the air pushed by hand ... that causes motion in the case of what is thrown...' [642,3] 'Rather, some incorporeal kinetic power must be transmitted by the thrower to the thing thrown, and the air that is pushed contributes either nothing at all or very little to this motion.'⁷⁶

But what if the medium itself were removed? Aristotle was prepared to consider this thought experiment, even though he regarded a void as impossible:

'...as there is no ratio of nought to a number... similarly the void can bear no ratio to the full, and therefore neither can the movement through the one to movement through the other, but if a thing moves through the thinnest medium such and such a distance in such and such a time, it moves through the void with a speed beyond any ratio...' ⁷⁷

In other words, movement through the void would occur instantaneously, which Aristotle regards as absurd. Therefore there is no vacuum or void anywhere. Aether fills the supra-lunar sphere, which is a plenum. The sub-lunar sphere is also a plenum, filled with the four elements.⁷⁸

Philoponus objected (quite validly) to Aristotle's argument that lack of resistance would result in infinite speed:

'...the time taken by each motion is proportional to the impulses inherent in the [moving] bodies, even if there is no obstruction... For if the medium is the cause of unequal motion *qua* obstruction, then the innate impulses must be the active causes. So even if the obstruction is removed, some time is taken by the motion of each thing – more or less of it in proportion to the greater or lesser impulse. ... If in general the reason why motion takes time were the physical [medium] that is cut through in the course of motion, and for this reason things that moved

⁷⁶ Sorabji (ed.) (2004), pp351-352

⁷⁷ Aristotle *Physics*, 215b19ff. in Barnes (ed.) (1995), p366

⁷⁸ Grant (1971), p42

through a vacuum would have to move without taking time because of there being nothing for them to cut through, this ought to happen all the more in the case of the fastest of all motions, I mean the [celestial] rotation. For what rotates does not cut through any physical [medium] either. But in fact this [timeless motion] does not happen: All rotation takes time, even without there being anything cut through in the motion.⁷⁹

Aristotle's error, identified by Philoponus and again by Avempace, is in assuming that body speed is inversely proportional to the density of the medium through which it travels. In fact, it is not the proportion of the density of two different media that dictates speed of an object in motion, but the resulting retardation of the respective media. Thus zero retardation (a void) allows zero reduction in speed; i.e. motion in a void is not absurd. Avempace, says Zimmermann, 'apparently subscribed to an impetus theory akin to that of Philoponus' but does not otherwise substantiate this assertion.⁸⁰ (It should be noted that similarities between the views of Philoponus and Avempace here are not on their own convincing evidence that scientific knowledge passed from the former to the latter. This point is discussed on p33f. below.)

Besides, Philoponus noted that Aristotle's suggestion that speed in a vacuum would be infinite had a major difficulty. The rotation of heavens (which Aristotle has surrounded by nothing) must itself encounter no resistance, but is demonstrably finite. This point was repeated by Avempace (which Sorabji notes is reported in Averroes' *Long Commentary on Physics 4*). Both Averroes and Aquinas attempt to rescue Aristotle from this problem, the former by suggesting that spheres provide their own resistance to turning, the latter by suggesting that Aristotle's connection of lack of resistance with infinite speed was merely a dialectical move against opponents who postulate vacuum as sole source of motion (although Sorabji disputes that Aristotle's opponents are ever so extreme).⁸¹

⁷⁹ Philoponus, *In Physics* 681,3-30 and 690,34-391,5 in Sorabji (ed.) (2004), p333

⁸⁰ Zimmermann (1987), p123

⁸¹ Sorabji (1990b), p197

Continuing his consideration of motion in a putative vacuum, Aristotle postulated a second absurdity. If no place in a vacuum differed from any other place:

‘...no one could say why a thing once set in motion should stop anywhere; for why should it stop here rather than here? So that a thing will either be at rest or must be moved ad infinitum...’⁸²

As Sorabji points out, this infers inertial motion and removes the requirement for an everlasting ‘prime mover’ that provides infinite power to keep the heavens turning. If aether is moving naturally and never changes (and therefore never gets exhausted or perishes) then why would movement stop?

But Philoponus regarded impetus as a force that exhausts over time, so motion in a vacuum would stop eventually (*In Physics* 644,16-22):

‘But I say that just as you [Aristotle] make the thrust of the air responsible for movement contrary to nature, and say that the thing moves until the moving force (*kinetikê dunamis*) is spent that was impressed in the air by the one who made the thrust in the first place, so clearly if something were moved contrary to nature upon a vacuum, it too would move until the moving force weakened that was impressed on the thing by the one who made the thrust in the first place.’⁸³

Philoponus’ changing notions of celestial dynamics

Philoponus’ notions on the subject developed over time and in this part of the discussion I want to trace those developments through his works, briefly demonstrating the way in which Philoponus eventually applied theories of local motion to the celestial sphere. From the quotations from *In Physics* above it is clear that, from the outset, Philoponus diverged from the basis of Aristotle’s theory of local motion which required that ‘everything that is in motion must be moved by something’.⁸⁴ Instead, Philoponus assigns to objects a natural place and an internal

⁸² Aristotle, *Physics* 4, 215b19ff in Barnes (ed.) (1995), p366

⁸³ Sorabji (ed.) (2004), pp335-336

⁸⁴ Aristotle *Physics* 7.1 241b34 in Barnes (ed.) (1995) p407 (echoing Plato, *Timaeus* 57E)

influence of motion and rest that imposes a ‘natural inclination’ to move: ‘...when stones are let go... it is rather the natural inclination (*phusikê rhopê*) in them that carries them down.’⁸⁵

Ten years later, Philoponus had grown yet more radical in his views on Aristotle’s mechanism of the causes of movement. In *Contra Proclum* he first abandoned Aristotle’s doctrine of causes in which contact-causality (or forced motion) is the efficient cause, and natural motion is motivated by final (or teleological) causes. Philoponus gave these up, firstly by repeating his abandonment of the external medium as a cause of forced motion, and also by eliminating final causality in respect of elemental movements towards a natural place. Internal forces replaced both causes.⁸⁶ But in *Contra Proclum* Philoponus turned his attention to celestial movements for this first time. He saw nothing mystical or unnatural there, comparing both celestial and sub-lunar rotations with those created by mechanical devices, e.g. centrifuges (*mechanemata*):

‘In general, what sort of necessity is there for one immediately to assume that the heaven is of a different nature than the four elements solely because the heaven moves in a circle? ... So, just as the ensemble of fire does not undergo circular motion by the agency of a natural impulse but is rather led around by the surrounding heaven (just as water is surely whirled around in a circle together with the machines) and this sort of motion belongs to the elemental fire (*hupekkauma*) itself in a way that is above its nature, so too the heaven, carried around in a circle by a mightier and incorporeal power and having this sort of motion in a way that is above the nature of its body, will not necessarily for this reason have to be of a different substance than the four elements except that the heaven enjoys this sort of motion immediately by the agency of an incorporeal nature whereas the interior things that move in

⁸⁵ Philoponus, *In Physics* 195,24-32 in Sorabji (ed.) (2004), p328

⁸⁶ Wolff (1987), p111

a circle [the *hupekkauma* and upper air] enjoy this sort of motion by means of the heaven.’⁸⁷

At this stage, Philoponus is implying the existence of an external, supernatural power rather than any suggestion of impetus, which he specifically excludes from heavenly motion. Simplicius, unusually when addressing Philoponus, finds something with which he can agree – he identified a potential accommodation between Philoponus and Aristotle on the problem of the moving firesphere and whether it can move naturally in a circle. Simplicius asserted that Aristotle (*De Caelo* 269a7-18) had never denied that sublunary elements can move in a circle, only saying that circular motion belongs to them neither naturally nor counternaturally. Therefore Simplicius agrees that such circular motion must be generated by supernatural means:

‘...but given that fire moves in a circle, does it move naturally or unnaturally? ...but it must be something other than natural, but rather by force. For there is such a thing as beneficial force which is not unnatural, but which might be called “preternatural”’.⁸⁸

Philoponus did not offer Simplicius much further opportunity to be agreeable, for in his soon following *Contra Aristotelem* (about 3 years subsequent to *Contra Proclum*) he contended, as reported by Simplicius in *In De Caelo* 34,5-11, that the movement of the heavens must be natural as nothing can move counter-naturally for ever. Therefore fire, for Philoponus, must have two natural movements – rectilinear and circular – which directly contradicts Aristotle’s axiom that a single simple body can only have, by nature, a single simple movement. In order to accommodate this change of view, Philoponus needed to break with Aristotle’s philosophical principle that matched simple bodies to simple movements on a one-to-one basis. He had two lines of argument to deploy. First, he attacked Aristotle's assumption that the celestial motion is circular on the basis that, in *De Caelo* 268b21 Aristotle defines circular motion as taking place about a centre. But the orbits of the planets had subsequently been shown by Ptolemy in the 1st century CE to be not circular, but eccentric and

⁸⁷ Philoponus *Contra Proclum* 492,5-493,5 in Sorabji (ed.) (2004), p344

⁸⁸ Simplicius, *In de Caelo* 21,1-25

complex.⁸⁹ As Philoponus put it, ‘The [planets] are clearly seen to reach a perigee and apogee.’⁹⁰

(Aristotle was apparently aware of the apparent change in distances of the nearer planets, recorded by Simplicius:

‘Aristotle also makes this clear in his *Physical Problems* when he introduces difficulties for the hypotheses of the astronomers on the basis of the fact that magnitudes of the planets do not appear equal.’⁹¹

The difficulty here is in fact a major impediment, for the theory of the aether within homocentric spheres as propounded by Aristotle is flatly incompatible with any system in which the planets vary their distance from the Earth. This issue was never resolved or even appears to have been mentioned by Aristotle in that context.)

Second, Philoponus attacked the validity of Aristotle's division of motion into celestial and sub-lunar segments on the grounds that rectilinear motion belongs to separable parts in the terrestrial world, but circular motion to the whole celestial sphere.^{92,93} Philoponus was able to quote from a corroborating precedent originally proposed by an earlier commentator (Themistius (317-c.387)) that bodies that have achieved their natural places cease to be heavy or light.⁹⁴ Simplicius makes his complaint clear:

‘He debases this too by saying that fire has two natural movements, the one in an upward direction [which belongs to] the parts of [fire] which have become detached from the totality, the other, a circular one, [which belongs to] the totality [itself], so that there is nothing to prevent

⁸⁹ Wildberg (1988), pp121-122

⁹⁰ Philoponus, reported in Simplicius *In de Caelo*, 32,1-11 – Philoponus, *Contra Aristotelem* [trans. Wildberg (1987)] p46

⁹¹ Simplicius, *In De Caelo* 505,24-26

⁹² Philoponus, reported in Simplicius in *In De Caelo* 33,17-20 – reported in Philoponus, *Contra Aristotelem* [trans. Wildberg (1987)] p46

⁹³ Wildberg (1988), pp124-125

⁹⁴ Simplicius, *In de Caelo*, 70,2ff – reported in Philoponus, *Contra Aristotelem* [trans. Wildberg (1987)] p61

the revolving heaven itself from consisting of fire, and the movement will not be contrary to nature. And it is clear that in all these [arguments] he led himself astray...'⁹⁵

Philoponus took his argument further. Given that fire can naturally partake of circular movement, nothing therefore prevents the heavens from consisting of fire, which implies heavens are perishable like sub-lunar region.⁹⁶ And so Philoponus achieved his overall philosophical objective – to deny the imperishability of the heavens and thus support his Christian doctrine on the reality of a beginning and end of the world, while at the same time invoking the authority of Plato (who also assigned a fiery element to the heavens) to do so. But we have now arrived at a critical part of the discussion. Philoponus' break with Aristotle's separation of the celestial and sublunar realms is very significant in relation to his speculations on cosmological dynamics because the obvious implication is that identical principles of motion can be applied in both domains.

Philoponus' final theory of celestial motion

In Wildberg's view, the application of impetus theory to celestial bodies is a natural outcome of three conditions. First, a metaphysical belief that the cosmos was brought into being by a Creator-God and that the Bible gives a valid account of this creation. Secondly, the development of a clear idea of the impetus theory as established by Philoponus in his commentary on *Physics*. Thirdly, the realisation that the movement of the celestial spheres can be regarded as natural, as argued in *Contra Aristotelem*, which took the first step towards demystifying curvilinear motion. Wildberg, having reviewed the historical evidence and finding these conditions met, therefore makes the 'tentative suggestion' that:

⁹⁵ Simplicius, *In De Caelo* 35,12-20 – reported in Philoponus *Contra Aristotelem* [trans. Wildberg (1987)], p48

⁹⁶ Wildberg (1988), p131

‘...the application of impetus theory to celestial spheres is in fact a plausible consequence of Philoponus' life-long concern with cosmological theory and Christian theology.’⁹⁷

If Wildberg’s position is to be criticised here, it is only to suggest that the second and third of his conditions above are by themselves necessary and sufficient for his suggestion to be regarded as valid in principle. The first condition is something of a precursor that started Philoponus on the road – but it is not itself necessary to his argument. And if all of Wildberg’s conditions were in fact fulfilled once *Contra Aristotelem* was completed, it raises an interesting historical question concerning why Philoponus then waited 25 years to promulgate the inference he had drawn. The answer may lie in the social and religious context in which Philoponus lived, but that is outside the scope of this discussion. I turn now to the actual evidence available for scrutiny set out in his final major work *De Opificio Mundi*.

It is the doctrine of the world soul with which Philoponus finally dispenses in *De Opificio Mundi*. He asks, what are the principles of motion of the heavenly bodies? Surely the God who created them would have instilled them with a principle of motion in the same way in which he instilled terrestrial bodies with heaviness and lightness?^{98,99} Philoponus responds to those who teach that the heavenly bodies are motivated by constant physical manoeuvring by angels, a notion which he ridicules:

‘What could be more ridiculous than this? Was God who created them unable to plant a motive power (*kinêtikên entheinai dunamin*) in the moon, the sun and the other heavenly bodies, as he planted inclinations (*rhopai*) in the heavy and light ones, and implanted in all animals the movements which come from the souls within them, so that the angels will not have to move them by force?’¹⁰⁰

⁹⁷ Wildberg (1988), pp245-246

⁹⁸ Wolff (1987), p97

⁹⁹ Verrycken (1990), p269

¹⁰⁰ Philoponus, *De Opificio Mundi* 28,20-29,9 in Sorabji (ed.) (2004), pp354-355

The phraseology itself is interesting, given the implication that movements in animals arise from the ‘souls within them’. The inference could be drawn that celestial movements might also require an initiating soul, a notion specifically rejected elsewhere in *De Opificio Mundi* as discussed here and on p13 above, and so this appears to be in inconsistency. Wildberg does not dwell on the matter, simply noting that this phrasing represents the earliest attempt to apply impetus theory to celestial spheres, anticipating medieval impetus theorists including Buridan and Oresme. But as Wildberg acknowledges, and as highlighted by Wolff in 1978, Philoponus’ application of impetus theory to the heavens may be nothing more than speculative hypothesis advanced for dialectic reasons.¹⁰¹

The progression of Philoponus’ dynamical theories over a 40-year period provides a number of different opportunities through which to detect his subsequent influence. Wildberg reviews his development of the ‘kinetic power’ (or impetus theory) set out in *In Physics*, the embracing of a Platonist soul and abandonment of the Aristotelian framework of the four causes in *Contra Proclum*, the natural and psychical circular movement of fire (and therefore the heavens) and corresponding abandonment of the terrestrial-celestial dichotomy in *Contra Aristotelem*, the natural turning of the firesphere in *In Meteorology* and the final abandonment of the world soul and impartation of a non-psychical impetus to the heavenly bodies in *De Opificio Mundi*. This is quite a heady mix, but the progress is incremental and towards a certain end. What started as a proposed resolution of a puzzling problem of projectile motion by the development of an impetus theory eventually gave Philoponus a philosophical basis underpinning his belief in a Creator-God responsible for the initiation of perpetual celestial movement.¹⁰²

With the development over time of Philoponus’ theories of motion now in mind, this discussion turns to the basic assertion that underpins Wildberg’s thesis: that Philoponus’ impetus theory passed by some means from late antiquity to Arabic commentators (including Avempace and Avicenna) and thence to Latin Europe, providing the beginnings of a basis of a new science of dynamics taken on and

¹⁰¹ Wildberg (1988), p242-243

¹⁰² Wildberg (1988), p243-244

perfected by the 14th century scholastics Jean Buridan (1295-1358) and Nicolas Oresme (c.1323-1382).

thesis

Influence of Philoponus on medieval dynamics

Early medieval ideas of motion

There are clear parallels between Philoponus' theories and those discussed by Aristotelian Arab thinkers. Sorabji notes, for example, that Avicenna maintained (in *Shifa* 1 p154f.) that only resistance exhausts the force in a projectile, and that in a vacuum such force would therefore not be exhausted, and that Buridan also insists that the impetus of God's creation of the universe will never run out.^{103,104} But if Wildberg's thesis that Philoponus may have anticipated dynamical theories on the celestial sphere that eventually led (via Buridan, Oresme and Galileo) to early modern notions of inertia is to be supported, then the link between Philoponus and the Aristotelian Arab philosophers needs to be established on a sound historical base.

The term 'Impetus Theory' was coined by Pierre Duhem in the early 20th century to describe the doctrine that motion arises from transmission of an exhaustible moving force that passes from a moving cause to a movable object, acting on it instantaneously. He described the doctrine as the notion that all motion requires a mover that transmits force, and that a moving force becomes exhausted over time.¹⁰⁵ Recognition by historians of science that the works of John Philoponus might share recognisable features with what we now know as impetus theory was apparently first proposed rather earlier, by Alexander von Humboldt in his 1847 work *Kosmos*. (Von Humboldt was likely the first to draw attention to Philoponus' assertion in *De Opificio Mundi* I.12 that the movements of celestial bodies can be explained by the transmission of force (*kinêtikên entheinei dunamin*) but it appears that von Humboldt's insight did not gain any historical purchase.) More significantly, the Galilean scholar Emil Wohlwill in various publications from 1883 to 1905 advanced his idea that there was a long tradition of the *vis impressa* doctrine that Duhem came to call the 'impetus theory'. But it was not until 1906 that Wohlwill first identified

¹⁰³ Sorabji (1990b), p198

¹⁰⁴ Clagett (1959), p513

¹⁰⁵ Wolff (1987), p84

Philoponus as originator of an impetus theory that extends in a continuous line from Philoponus to classical mechanics.¹⁰⁶

Wohlwill's view has significant support today. But for modern historians the identification of the pathway of such transfer of knowledge, the drawing of a plausibly unbroken line of scientific communication that connects Philoponus with Galileo, remains the problem. This has been the subject of much more recent historical investigation, the validity of which I now intend to review.

Validity of historiographical arguments concerning Philoponus' influence

Sorabji, at least as far as terrestrial dynamics is concerned, was more or less convinced that the unbroken line existed. He argued in materials first prepared for his 1988 book *Matter, Space and Motion* that Philoponus must be seen as the originator of impetus theory defined as an internal force impressed from without.¹⁰⁷ But in a 1990 book that he edited, Sorabji went further:

‘...the introduction of the impetus theory into dynamics, which has been called a scientific revolution [presumably by Thomas Kuhn (1962)¹⁰⁸, p119], has been held to be an independent invention of the Latin West, even if it was earlier discovered by the Arabs or their predecessors. But recent work has traced a plausible route by which it could have been passed by Philoponus, via the Arabs, to the West.¹⁰⁹

The ‘recent work’ which Sorabji cites is a brief treatise ‘Philoponus’ Impetus Theory in the Arabic Tradition’ by Fritz Zimmermann, published in Sorabji’s edited book *Philoponus and the Rejection of Aristotelian Science* in 1987. Zimmermann’s thesis supported Shlomo Pines’ contention (in various scholarly treatises from 1938 to 1961)

¹⁰⁶ Wolff (1987), pp86-88

¹⁰⁷ Sorabji (1990b), p195

¹⁰⁸ It is not clear that Kuhn actually designated impetus theory as a ‘scientific revolution’, although he did describe it as a ‘medieval paradigm’ in *The Structure of Scientific Revolutions* (1962 [3rd edition 1996]), p119, and as a significant contribution to the Copernican Revolution (*The Copernican Revolution* (1957), pp119-123.

¹⁰⁹ Sorabji (1990a), p25 (my emphasis)

that (1) the theory of motion promoted by Avicenna resembled the impetus theory of Philoponus (2) some of some of Philoponus' arguments were known to Arab philosophers before and after Avicenna, and (3) the impetus theory of later Latins (Buridan and Oresme) was likely to have been inspired by Arabic tradition of Philoponus.¹¹⁰

Shlomo Pines (1908-1990) was a respected scholar of Jewish and Islamic philosophy. He asserted for many years (beginning in 1938) that there was a contestable argument for the identification of Philoponus' influence in the impetus theories of Buridan and Oresme. In the Muslim East it was Avicenna, according to Pines, who first presented an impetus theory that:

‘...all the [Aristotelian] Arabic philosophers in the Muslim East, among whom [Avicenna] was undoubtedly the leader [...], professed a theory which was similar or identical to the impetus theory or to [the views held by] Philoponus.’¹¹¹

The main basis of Zimmermann's supporting thesis is an analysis of the textual correspondence of language and ideas between Philoponus and an epitome of Avicenna's philosophy produced by Ghazali (d.1111) in his *Maqāsid al-Falāsifa* ('*Intentions of the Philosophers*'). For example, Avicenna (according to Ghazali) uses the Arabic word *mayl* to represent impetus, or the natural inclination of the elements to cause 'fire to rise or stones to fall'. *Mayl* translates from the ancient Greek *rhopê* ('inclination'), often used by Philoponus to represent impetus. Zimmermann makes the obvious (to him) connection that Avicenna's natural *mayl* was 'clearly the same as Philoponus' natural *rhopê*'.¹¹² Secondly, Zimmermann finds that 'Avicenna in the East and Avempace in the West both share Philoponus' view that *motus separatus* in inanimate bodies is caused by an internal mover'. This, together with other objections to Aristotelian dynamics raised by Avicenna and echoing those of Philoponus, makes it 'natural to assume that some of Philoponus

¹¹⁰ Zimmermann (1987), p121

¹¹¹ Pines (1938), 'Les précurseurs musulmans de la théorie de l'impetus', reported in Franco (2004), p527

¹¹² Zimmermann (1987), p121-123

criticism of Aristotle was available in Arabic'.¹¹³ But Zimmermann's thesis has a problem, which he himself acknowledges – when discussing theories of motion, the Arabic Aristotelians gave little credit to Philoponus.¹¹⁴ Zimmermann thus builds a remedial argument that the Arab Aristotelians were both 'less than completely aware of Philoponus' influence on their reading of Aristotle' and also 'reluctant to say that they were following Philoponus [presumably on theories of motion only] even when they knew they were'.¹¹⁵ This appears a peculiar argument if Zimmermann is trying to support his thesis that the impetus theory is carried along an unbroken philosophical line – either the Arabs were aware of Philoponus' influence or they were not, and not only has Zimmermann failed to establish that Arab philosophers were definitely aware, in fact he now questions the extent to which they were.

Philoponus, said Zimmermann, was best known in the Arab world for his criticism of Aristotle's belief in the eternity of the world.¹¹⁶ This can be accepted without question – Philoponus was in fact revered by Arabic philosophers, and Zimmermann acknowledged that both Avempace and Avicenna refer to Philoponus by his Arabic name Yahyā al-Nahwī ('John the Grammarian'). But it is difficult to see how this sits with Zimmermann's previous argument that the Arabs may have been reluctant to say they were following Philoponus when, in fact, they did so respectfully on other occasions. And on the motive for this putative reluctance, Zimmermann suggested that in the eyes of posterity Philoponus had 'doubly disgraced himself' by embracing the Tritheist faction of the Monophysites and for his attacks on Aristotle.¹¹⁷ But Zimmermann failed to explain, firstly, how Philoponus' status as a disgraced Christian would matter to Muslim Arabs and, secondly, why the Arabs were happy to mention Philoponus with honour elsewhere. So Zimmermann's argument is now in tatters.

¹¹³ Zimmermann (1987), p124

¹¹⁴ In discussion with Professor Sharples on 20 August 2008, he explained that it was not uncommon for Arabic philosophers to neglect mentioning their sources if they were in agreement with them, so this point is not necessarily fatal to Zimmermann's thesis.

¹¹⁵ Zimmermann (1987), p124

¹¹⁶ Zimmermann (1987), p124

¹¹⁷ Zimmermann (1987), pp125-127

In the end, Zimmermann relied on his view that ‘it would be odd... if the emergence in thirteenth/fourteenth-century Europe of Latin impetus theories owed nothing to the discussion stimulated in antecedent Arabic and Hebrew philosophy by Avicenna's version of the impetus theory of Philoponus.’¹¹⁸ He may not be wrong – but stripped of inconsistent lines of reasoning, Zimmermann's argument that Philoponus' impetus theory influenced the Aristotelian Arabs appears to be based on the usage of *mayl* to translate *rhopê* and a feeling that ‘it would be odd’ if it were not so. Zimmermann's historical thesis is thus not established and I therefore believe that Sorabji has placed rather undue reliance on Zimmermann's brief work.

But Sorabji's argument is not grounded solely on Zimmermann's work. In a careful and scholarly treatise ‘Infinite Power impressed: the transformation of Aristotle's physics and theology’ published in 1990, Sorabji traces the arguments set out by Philoponus on the question of the eternity of the world into the texts of Averroes, which provide an important part of the case for the proponents of Philoponus' direct influence on medieval theories of dynamics. It is generally accepted that Averroes had an important influence on later Christian and Jewish thinkers – his *Long Commentary on Physics 8* and *Long Commentary on Metaphysics 12*, both of which refer by name to Philoponus and specifically to his argument against the eternity of the world, were translated into Latin from Arabic by Michael Scot in the 13th century, by which route they became known to Robert Grosseteste (c.1175-1253) and Roger Bacon (1214-1294) in Oxford, and Bonaventure and Thomas Aquinas in Paris.¹¹⁹

In these texts (and in others detailed by Sorabji), Averroes addresses the argument concerning the infinite power required to keep the celestial spheres turning for ever. The issue has implications for dynamics and specifically for Wildberg's thesis on the application of impetus to celestial bodies, for Aristotle's question (discussed on p24 above) concerning why motion in a vacuum would ever stop if no stopping place in a vacuum is different from any other, had been specifically endorsed by Avicenna.¹²⁰ In addition, Averroes reported that Avempace denied Aristotle's claim that the time of

¹¹⁸ Zimmermann (1987), p128

¹¹⁹ Sorabji (1990b), pp193-194

¹²⁰ Sorabji (1990b), p196

fall of a body is directly proportional to the density (and therefore the resistance) of the external medium. Avempace repeated Philoponus' argument that, if celestial bodies moved through an unresisting medium (as Aristotle claimed was the case with aether) differing finite speeds could be observed, thus harming Aristotle's position. Avempace concluded that, not only was resistant medium not required for motion, but that its sole function was to retard motion. Thomas Aquinas appears to have been influenced by Avempace's view of the aether and the motion of celestial bodies. He repeats Avempace's illustration of motion through the celestial aether.¹²¹

Averroes, and later Thomas Aquinas, had to 'rescue' Aristotle from this difficulty, the former by postulating an in-built resistance to motion in the heavenly spheres, the latter suggesting (even more questionably) that Aristotle's position on the point was raised merely dialectically.¹²²

The sum total of Sorabji's argument concerning the influence of Philoponus on medieval theories of impetus thus rests on the weight of indirect evidence. He showed that the Medieval Latin sources of Impetus Theory (Buridan and Oresme) seem 'astonishingly' close to Philoponus. Buridan made Philoponus' point that violent mechanical agitation of air will not move a stone very much and also shared the view that stellar movement is due to impressed impetus by God at the moment of creation. Sorabji provides a plausible possible pathway for the transmission, via Avicenna, of the idea of impetus as an internal force in terrestrial bodies – the Latin of Ghazali's summary was available in the latter part of the 12th century even though Avicenna's work was not translated until later.¹²³ Philoponus' argument on the eternity of the world was available in Arabic in summary and also in translations of *Contra Proclum* and *Contra Aristotelem*. Given that Avicenna commented explicitly on Philoponus in his commentary on the *Metaphysics* and, in part at least, adopts Philoponus' views, Averroes later concurs that Avicenna follows Philoponus.¹²⁴ There is no doubt that Sorabji's case is persuasive.

¹²¹ Grant (1971), pp42-43

¹²² Sorabji (1990b), p197

¹²³ Sorabji (1988), p237

¹²⁴ Sorabji (1990b), pp185-188

Wildberg's thesis is not saved by Sorabji's evidence however, weighty though it may be. Islamic writers did not assign impetus as an impressed force to the movement of the heavens, in which case it is not clear how it might have come to Buridan unless by original development. Sorabji conjectures that the Arab Aristotelians may have had no interest in the Christian work *De Opificio Mundi*; it is also possible that there was a constraining tension between scientific philosophy and Koranic exposition. But I would argue that in either case the substantial majority of Philoponus' output was in defence of his Christian viewpoint to which, Sorabji showed, the Aristotelian Arabs were happy to refer with respectful interest; so there is an inconsistency in Sorabji's view.

This summarises the current historiographical commentaries by historians who acknowledge, to one extent or another, the influence of Philoponus' theories of motion on medieval theories of dynamics. The evidence concerning terrestrial dynamical theories is weighty but not completely convincing, and needs to be treated with due caution. The evidence concerning celestial dynamics is slight, as will be discussed below. But for the moment I want to focus on the evidence against the notion that Arab philosophers were influenced by the dynamical theories of Philoponus. Historians who argue against this weight of evidence are thin on the ground, but the German social historian Michael Wolff proposed a novel approach to Philoponus' ideas.

Wolff began, in his article 'Philoponus and the Rise of Preclassical Dynamics' in Sorabji's edited 1987 book *Philoponus and the Rejection of Aristotelian Science*, by denying that Philoponus provided a link between Aristotelian physics and classical mechanics. He departed from traditional historical analysis however by asking if it is 'not more appropriate ask about the origin and kind of *ethical problem* to which impetus theory helped to provide an answer?'¹²⁵ Relying on the view that, in ancient philosophy, particular interpretations of natural phenomena are consequences of contextual ethical and practical considerations, Wolff identifies common motivations of 'freedom and spontaneity' throughout Philoponus' writings. He quotes three examples concerning free will (in *Corollary on the Void*), forced motions (in *In*

¹²⁵ Wolff (1987), p120 – his emphasis

Physics) and the denial of teleological causes (also in *In Physics*) – that latter two are discussed above. It is not unconnected, conjectures Wolff, that impetus theory involving the exhaustion of physical activity over time was a product of the period of late antiquity when the context of a culture built on slave labour was changing.

I personally do not find this in the least convincing, but whether or not Wolff has reached a valid conclusion on this point is outside the scope of, and irrelevant to, this discussion. What is relevant is Wolff's denial of a link between Philoponus and classical mechanics, the evidence for which I now intend to examine.

Wolff focuses on Wohlwill's early 20th-century assertion linking Philoponus impetus theory with the dynamics of Galileo, exploring whether Wohlwill's views are 'still tenable' in light of new knowledge on classical mechanics.¹²⁶ This is immediately problematic, as Wolff has not indicated why he was attacking 100-year old historiography in support of his main thesis when much more recent scholarly studies were available (of which the best example is probably by Pines).

Next, Wolff traces the history of impetus theory, which he compares to:

‘...the modern Law of Conservation of Energy, according to which a dynamic quantity (energy) is exhausted and consumed whenever a change of state occurs.’

One might question the historical appropriateness of this comparison from a number of viewpoints – but in any event it confuses the First Law of Thermodynamics (conservation of energy) with the Second Law (entropy increases to a maximum).¹²⁷

Next, Wolff describes Impetus Theory as being in the nature of a speculative theory, rather than empirical. Wolff considers that this is the reason that it is difficult to regard the theory as a connecting link between Aristotelian physics and classical mechanics, because lack of empiricism destroys the continuity of evolution from one to the other. Wolff says:

¹²⁶ Wolff (1987), p88

¹²⁷ Wolff (1987), p85 – Definitions from Bynum, Brown & Porter, Dictionary of the History of Science (1984), ‘heat and thermodynamics’

‘If emphasis is placed on the continuity of the transition, it is puzzling that structures which were suited to modern empirical science could be ‘prepared for’ by a merely speculative theory.’¹²⁸

This too is unconvincing, because Wolff has not defined his terms. Is ‘observation’ not ‘empirical’? And was Philoponus not utilising ‘observation’ in the construction of his ideas on objects in motion? Also, ‘speculative’ is not a defined term – and it must be arguable that all modern ‘empirical’ theories were ‘speculative’ at some stage of their development. There has to be a point where any non-empirical theory becomes empirical – is Wolff implying that all continuities break down at that point? Some would argue, from a philosophical perspective, that all scientific theories are permanently speculative by their nature. It is therefore not clear how a change of status from ‘speculative’ to ‘empirical’ acts to destroy continuities of historical scientific development. So Wolff’s perspective here does not appear to stand up to critical scrutiny.

In terms of the discussion here Wolff has not demonstrated that his subsidiary thesis, *viz.* that there is no continuity of scientific development between Philoponus and early modern theories of dynamics, is supported by the evidence he provides. His main thesis – that impetus theory may have been an answer to a particular ethical problem – does not in any event preclude the continuity of the influence of impetus theory on later thinkers.

Overall, the historians leave us with a balanced conclusion, having neither convincingly established nor rebutted the thesis that Philoponus’ theories of motion influenced early modern development of celestial mechanics. They have, however, provided a significant weight of evidence on several subsidiary issues, with which this discussion concludes.

¹²⁸ Wolff (1987), p86

Conclusion

Aristotle's theory of the aether arose from clear evidence that the observable universe is divided into two parts – the terrestrial world where objects are heavy (and drawn to the centre) or light (seeking the celestial sphere); and the celestial realm, which is unchanging and ceaselessly rotating. The laws of motion assigned by Aristotle to the two realms reflected the difference in nature of each; and his philosophical system of analogy and syllogism, the axiological status and geometrical perfection of the circle and (probably) beliefs from his pagan background led him to the hypothesis that as life and objects on earth were corrupt and perishable, so celestial matter (the aether) must be different – i.e. it must lack these qualities.

As a Christian, Philoponus had a significant problem with an unchanging aether with the attribute of eternal existence. Philoponus' God had decreed, in terms that Philoponus found acceptable, that the world had a beginning. Therefore the aether as hypothesised by Aristotle had to be rejected. As others have pointed out however, Aristotle built well-integrated philosophical systems that lasted. An attack on one element (literally, in this case) forced an unwelcome unravelling elsewhere and the consequences were more-or-less endless. So Philoponus needed to build an equally robust system of philosophical statements and conclusions with which he could dispute the eternity of the world – and that meant following the unravelling process of Aristotle's syllogisms from the removal of the aether as an ontological entity, and consequently the replacement of Aristotle's system of sublunar dynamics from which the qualities of the aether had been deduced by analogy.

Whether or not he was successful is not a matter for this discussion. Certainly the challenge was robustly made, and there may be reasons relating to Philoponus' condemnation as a heretic and anathema to the established church for his works being less influential than they might have been. I have discussed evidence that shows Philoponus' originality and, in some ways, his modern approach to science, in particular his desire for parsimony in scientific explanation and his dependence on evidence, without which he eliminated otherwise plausible hypotheses. But all that is by the way, for what this discussion has shown is that Philoponus' theories developed incrementally over time, always in the direction of supporting his Christian view on the generability and perishability of the world. It has proved more difficult however

to demonstrate that his philosophical works influenced posterity in any significant way. Insofar as his theories of dynamics were read and accepted by the Aristotelian Arabs and thence transmitted to the Latin west, there is no available evidence to show that they were clearly attributed to him. Insofar as the Aristotelian Arabs were content to discuss and attribute lines of philosophical thought to Philoponus, those thoughts were not (generally) to do with his dynamical theories. And insofar as the Latin west developed new theories of motion including the assignment of an impetus to the heavens, they appeared similar to Philoponus' hypotheses – yet a clear path by which that knowledge may have passed has not yet been rigorously identified.

Most historians appear to have been convinced that 'something from Philoponus' did reach the Latin west. The weight of indirect evidence set out by Sorabji is particularly persuasive, and even if it is treated with due caution the conclusion here is that there something of the influence of Philoponus' dynamics discernible in the output of Avempace, Avicenna, Averroes and subsequently Buridan, Oresme and therefore Galileo. So deconstructing Wildberg's thesis with this weight of evidence in mind leads me to the following conclusions. First, the impact of Philoponus generally on Aristotelian Arabs is clearly established by the regular and respectful attribution of philosophical ideas to Yahyā al-Nahwī (John the Grammarian). Second, the influence of Philoponus, through Avempace, Avicenna and Averroes on Grosseteste and Bacon (and thus on later medieval thinkers Buridan and Oresme, and hence to Aquinas and the early modern period generally) is established by the preponderance of evidence set out by Sorabji (1990b). It appears unlikely in the extreme, apart from all other considerations, that Buridan's use of the example of the moving stone and agitated air would have been developed by him independently. Thirdly, that Philoponus' impetus theory was read and developed by Avicenna (consequently providing a path for knowledge transfer to Latin Europe) is persuasively, but not comprehensively, established. Zimmermann's arguments (beginning on p33 above) are not strong, and yet the correspondence of language tips the balance of probabilities in favour of him being correct, I believe, although I fully accept that this is not an indisputable conclusion. Finally, I reject the final step – that the application of a form of impetus theory to the heavens was itself anticipated by Philoponus and passed by any plausible route to early modern Europe. The main reason for this rejection is the paucity of the theory itself – a single relatively obscure paragraph in a work written, in the main, to

account for the Mosaic account of the origin of the world, does not have sufficient substance, in my view, to account for the much clearer description by Buridan of an ‘impressed impetus’ by God at the moment of creation. It must be said that the existence of this example from Buridan is potentially rather damaging to my conclusion, but then it is possible to fall back on the lack of any corroborating evidence, as Sorabji explained (p38 above), that the Aristotelian Arabs had even read *De Opificio Mundi*. And if it did not pass through the Arab philosophers, there is no means by which it could have reached Buridan.

There is one final point I would like to make. It concerns the question of the paucity of evidence supporting the recognition by historians (not least Sorabji himself), in *De Opificio Mundi*, of the application of impetus theory to the heavens. The text (see p29 above) now made available in English translation seems to provide only thin support for the excitement generated by Wildberg and others who believe, on the basis of these lines, that Philoponus ‘anticipated’ the application of impetus theory to the heavens by Buridan. The text itself is ambiguous and conflates the idea of motion with the existence of a soul, a notion that Philoponus specifically refutes elsewhere in the text. And Philoponus’ paragraph must be seen in its context as a comment ridiculing the opinion of a theologian who ascribed celestial movements to angels. So I suspect that Wolff is closer to the truth when he suggests that Philoponus’ comment is little more than a speculative supposition advanced for dialectic reasons.¹²⁹

My closing comment, then, is itself a question. It can be argued – in fact I do argue – that there is a danger, in this case at least, of historiography building significant conclusions based on insufficiently rigorous foundations. So the question is this – to what extent does the excitement of the search for antecedents of ‘modern’ scientific theories tend to reduce criteria for historical scrupulousness in the assessment of historical evidence? And with a mild warning that the criteria may have been thus lowered in the case of Philoponus and his celestial impetus theory, that seems a good place to end.

(12,186 words excluding footnotes and bibliography)

¹²⁹ Wildberg (1988), p242-243

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