AVERROES' NATURAL PHILOSOPHY AND ITS RECEPTION IN THE LATIN WEST

Edited by
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LEUVEN UNIVERSITY PRESS

Leuven University Press / Presses Universitaires de Louvain /
Universitaire Pers Leuven
Minderbroedersstraat 4, B-3000 Leuven (Belgium)

ISBN 978 94 6270 046 8
D/2015/1869/48
NUR: 732

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AVERROES' CRITIQUE OF PTOLEMY AND ITS RECEPTION BY JOHN OF JANDUN AND AGOSTINO NIFO

Dag Nikolaus Hasse*

In medieval cosmology, many disputes are rooted in a basic tension between Aristotelian physics and Ptolemaic astronomy. In his main work of astronomy, the *Almagest*, Ptolemy uses several mathematical devices to calculate the course of the planets, most notably the so-called eccentric and epicyclic circles that rotate around centres other than the centre of the earth. In Aristotle's universe, however, all planetary spheres are strictly concentrical. The tension between these traditions surfaced in several textual genres, one of them being the commentary tradition on Aristotle and Ptolemy. Among the key texts that sparked cosmological discussions was book Lambda of Aristotle's *Metaphysics*. The present paper will focus on three medieval commentators on book Lambda, who are particularly outspoken about their cosmological standpoint: Averroes, John of Jandun, and Agostino Nifo.

In chapter Lambda 8 of the *Metaphysics*, Aristotle discusses the number of unmoved movers. For this purpose, he turns to the planetary theories of two astronomers: the famous Eudoxus of Cnidos, who is a generation older than Aristotle, and Aristotle's contemporary Calippus. Eudoxus' planetary theory was of great historical importance, since it much influenced subsequent Greek astronomy and cosmology, including Aristotle's – even if it was rejected soon. It makes full use of the idea that the earth is spherical and that the heavens can be described as spherical too, and uses geometrical models for the description of planetary movements. Eudoxus assumed that sun and moon are moved by three spheres each, and that the planets are moved by four spheres each. The combination of several spherical movements is meant to explain the westward daily movement, the eastward zodiacal movement and, in case of the planets, their occasional retrogradate movements. All in all, in Eudoxus' system, 26 spheres are needed to explain the movements of the heavens.[1] Calippus increased the number of spheres involved (about this not much is known),

* I am grateful for criticism and advice from the participants of the Nijmegen colloquium and from Edith Sylla in particular. I am also grateful for the help of Stefan Georges and David Juste. Research for this article was funded by the Volkswagen Foundation.

[1] On Eudoxus see J.D. North, *The Fontana History of Astronomy and Cosmology*, London: Fontana Press, 1994 (Fontana history of science), 67–77; J. Evans, *The History and Practice of Ancient Astronomy*, New York [etc.]: Oxford University Press, 1998, 305–312; and G.E.R. Lloyd, 'Metaphysics Λ 8,' in: M. Frede & D. Charles (eds), *Aristotle's* Metaphysics *Lambda*. Symposium Aristotelicum, Oxford: Clarendon Press, 2000, 245–274, at 256–259.

and Aristotle did so again, but for a different reason: Aristotle wanted to explain the heavens as a physical mechanism, in which a rolling sphere influences the next adjacent sphere. In order to explain why the movement of the outer spheres does not influence or distort the movement of the inner spheres, Aristotle assumed the existence of 'unrolling spheres,' that is, spheres that move in the opposite direction and thus cancel out the motion of the 'rolling spheres.' The planet of Saturn, for instance, comprises four rolling and three unrolling spheres, with the effect that it can contain the next lower planet Jupiter without distorting the motion of this planet. Aristotle thus assumed the existence of 55 spheres (or 49 or 47, if Calippus' inventions are not counted). And Aristotle concluded that this also is the number of the eternal unmoved movers of the spheres.[2] Several centuries later, Ptolemy, in his *Planetary Hypotheses*, will reject several tenets of Aristotle's astronomy and will criticize the assumption of 'unrolling spheres' in particular.[3] At the same time, he continues the cosmological tradition of Eudoxus and Aristotle by describing the cosmos in terms of concentric and solid spheres and by adopting much of Aristotle's physics.

When, towards the end of the twelfth century, Averroes wrote his long commentary on this passage of the *Metaphysics*, he found that Ptolemy's astronomy, which was the ruling astronomy of his day, was in conflict with the physical principles of Aristotelian cosmology. Averroes argued that the eccentrics and epicycles, which Ptolemy had used to calculate the planetary motions, are not real or physical, and that, hence, the astronomy of his day is useful only for calculation, but 'extraneous to nature' (*ḫāriǧ 'an al-ṭab'*[4] – or, in Michael Scot's Latin translation: *ecentricum*

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[2] Lloyd, 'Metaphysics Λ 8,' 259–263; and M. Bordt, *Aristoteles'* Metaphysik *XII*, Darmstadt: Wissenschaftliche Buchgesellschaft, 2006 (Werkinterpretationen), 127–138.

[3] Ptolemy, *Opera astronomica minora*, ed. J.L. Heiberg, Leipzig: Teubner, 1907 (Opera quae extant omnia, 2), 114–115 (German translation of part II of the *Planetary Hypotheses*); B.R. Goldstein, 'The Arabic Version of Ptolemy's Planetary Hypotheses,' *Transactions of the American Philosophical Society. New Series*, 54 (1967), 3–55 (with English translation of book I.2 of the *Planetary Hypotheses*); see L.C. Taub, *Ptolemy's Universe: The Natural Philosophical and Ethical Foundations of Ptolemy's Astronomy*, Chicago [etc.]: Open Court, 1993, 114–119. For a brief but useful summary of the *Planetary Hypotheses* see N.S. Hetherington (ed.), *Encyclopedia of Cosmology: Historical, Philosophical, and Scientific Foundations of Modern Cosmology*, New York [etc.]: Garland, 1993 (Garland reference library of the humanities, 1250), s.v. 'Ptolemy's Cosmology,' 536–541.

[4] Averroes, *Tafsīr mā ba'd aṭ-ṭabī'a*, ed. M. Bouyges, 3 vols, Beirut: Imprimerie Catholique, 1938–1952 (Bibliotheca Arabica Scholasticorum. Serie arabe, 5–7), 3: 1661[8–9]. For English and French translations of Averroes' long commentary on book Lambda see Ch. Genequand, *Ibn Rushd's Metaphysics: A Translation with Introduction of Ibn Rushd's Commentary on Aristotle's Metaphysics, Book Lām*, Leiden [etc.]: Brill, 1984 (Islamic philosophy and theology,

enim aut epicyclum dicere est extra naturam).[5] In this critique of Ptolemy, Averroes was not alone, as has repeatedly been pointed out in scholarship.[6] Averroes was the heir of two trends: first, the general trend of Arabic astronomers to write treatises of *šukūk*, doubts or objections against Ptolemy, in an attempt to reform Ptolemaic astronomy, such as Ibn al-Hayṭam's *Šukūk*. This treatise is particularly critical of Ptolemy's 'equant,' the *punctum aequans*, which regulates the speed of circular motion, by making it slower or faster – a clear departure from uniform motion, which many astronomers objected to, among them Nicolaus Copernicus.[7] The second trend is the specifically 'Andalusian revolt' against Ptolemy's astronomy, as A.I. Sabra has called it, by Ibn Bāǧǧa, Ibn Ṭufayl, Averroes, al-Biṭrūǧī, and Maimonides. These authors rejected eccentrics and epicycles altogether because they found them to be in conflict with the Aristotelian physics of concentric spheres. Of these four authors, only al-Biṭrūǧī has attempted to write a full-fledged astronomical treatise, the *Kitāb fī l-hay'a* (*On astronomy*), composed around 1200 and soon afterwards translated into Latin by Michael Scot. The most common among the various Latin titles was *De motibus celorum*. Al-Biṭrūǧī accepted only Aristotelian concentric

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1), and A. Martin, *Averroès: Grand commentaire de la Métaphysique d'Aristote (Tafsīr mā ba'd al-ṭabī'a): livre Lam-Lambda*, Paris: Les Belles Lettres, 1984 (Bibliothèque de la Faculté de Philosophie et Lettres de l'Université de Liège, 234).

[5] Averroes, *In* Metaphysicam, in: *Aristotelis opera cum Averrois commentariis*, 8, Venezia: Apud Junctas, 1562–1574 (repr. Frankfurt am Main: Minerva, 1962), comm. 45, 329vaG. That Michael Scot is the Latin translator of the long commentary on the *Metaphysics* is shown by D.N. Hasse, *Latin Averroes Translations of the First Half of the Thirteenth Century*, Hildesheim: Olms, 2010.

[6] On Averroes' astronomy and its sources see P. Duhem, *Le système du monde. Histoire des doctrines cosmologiques de Platon à Copernic*, Paris: Hermann, 1913–1959, 2: 132–139; F.J. Carmody, 'The Planetary Theory of Ibn Rushd,' *Osiris*, 10 (1952), 556–586; A.I. Sabra, 'The Andalusian Revolt Against Ptolemaic Astronomy: Averroes and al-Biṭrūjī,' in: E. Mendelsohn (ed.), *Transformation and Tradition in the Sciences*. Essays in Honor of I. Bernard Cohen, Cambridge (MA): Cambridge University Press, 1984, 133–153 (repr. in A.I. Sabra, *Optics, Astronomy and Logic: Studies in Arabic Science and Philosophy*, Aldershot: Ashgate, 1994 [Variorum collected studies series, 444], art. XV); J. Samsó, 'On al-Bitruji and the Hay'a Tradition in al-Andalus,' in: J. Samsó, *Islamic Astronomy and Medieval Spain*, Aldershot: Ashgate, 1994 (Variorum collected studies series, 428), art. XII, 1–13; J. Lay, '*L'Abrégé* de l'Almageste: Un inédit d'Averroès en version hébraïque,' *Arabic Sciences and Philosophy*, 6 (1996), 23–61; and G. Endress, 'Mathematics and Philosophy in Medieval Islam,' in: J.P. Hogendijk & A.I. Sabra (eds), *The Enterprise of Science in Islam: New Perspectives*, Cambridge (MA), London: MIT Press, 2003 (Dibner Institute studies in the history of science and technology), 121–176, at 148–157.

[7] See A.I. Sabra, 'Ibn al-Haytham,' in: C.C. Gillispie (ed.), *Dictionary of Scientific Biography*, New York: Charles Scribner's Sons, 1970–1980, 6: 189–210, at 197–198.

spheres – that is, only one centre for the entire universe for all spheres, and no cycles around other centres – and only constant, uniform motion. The problem then was how to account for the apparent irregularities in the movement of sun, moon, and planets. Al-Biṭrūǧī's solution was to make the spheres rotate around poles that rotate themselves around poles, the effect being a kind of 'spiral motion.'[8]

Averroes discusses the conflict between Ptolemaic astronomy and Aristotelian physics several times in his œuvre, notably: (1) in the *Epitome* of the *Metaphysics*;[9] (2) in the *Epitome* of Ptolemy's *Almagest* (*Muḫtaṣar al-Maǧisṭī*), which is extant only in Hebrew and still unpublished;[10] (3) briefly in the *Epitome* on *De caelo*;[11] (4) in the long commentary on *De Caelo*, book II, chapter 35,[12] and (5), most extensively, in the long commentary on the *Metaphysics*, book Lambda, chapters 44–47. In this last text, which dates to the 1190s, Averroes looks back at his engagement with astronomy:

> In my youth, I had hoped to accomplish this investigation, but now in my old age I have despaired of that, having been impeded by obstacles. But let this discourse spur someone else to inquire into these matters (further). For nothing of the (true) science of astronomy exists in our time, the astronomy of our time being only in agreement with calculations (*al-ḥusbān*) and not with what exists (*al-wuǧūd*).[13]

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[8] Sabra, 'The Andalusian Revolt,' 136–137. For the Arabic text see al-Biṭrūǧī, *On the Principles of Astronomy*, ed. B.R. Goldstein, New Haven [etc.]: Yale University Press, 1971 (Yale studies in the history of science and medicine, 7). For Michael Scot's Latin translation, see al-Biṭrūǧī, *De motibus celorum*, ed. F.J. Carmody, Berkeley [etc.]: University of California Press, 1952.

[9] Averroes, *On Aristotle's* Metaphysics. *An Annotated Translation of the So-called* Epitome, ed. R. Arnzen, Berlin [etc.]: De Gruyter, 2010 (Scientia Graeco-Arabica, 5), 146–150, with Arnzen's notes on 308–314.

[10] On this text, see Lay, 'L'*Abrégé* de l'Almageste.'

[11] See Endress, 'Mathematics and Philosophy,' 152.

[12] The long commentary on *De caelo* is only partially extant in Arabic. For chapter II.35, which is extant, see Averroes, *Commentary on Aristotle's Book on the Heaven and the Universe: Sharḥ kitāb al-samā' wa-l-'ālam. With an introduction by Gerhard Endress. Reproduced from MS 11821, National Library, Tunis (Aḥmadiyya Fund, 5538)*, Frankfurt am Main: Institute for the history of Arabic-Islamic science at the Johann Wolfgang Goethe University, 1994 (Publications of the Institute for the history of Arabic-Islamic science. Series C, Facsimile editions, 57), 208–211. For the Latin version, see Averroes, *Commentum magnum super libro* De celo et mundo *Aristotelis*, ed. F.J. Carmody & R. Arnzen, 2 vols, Leuven: Peeters, 2003 (Recherches de Théologie et Philosophie médiévales. Bibliotheca, 4), 2: 330–332.

[13] Averroes, *Tafsīr mā ba'd al-ṭabī'a*, 1664$^{2-7}$. The translation is from Sabra, 'The Andalusian Revolt,' 142.

In the *Epitome* of the *Metaphysics*, which dates from the 1160s in its earliest version,[14] Averroes does not yet reject Ptolemy's eccentrics; instead, he departs from Aristotle's principle of concentric spheres. Nonconcentric spheres, Averroes argues, are possible, since it is not necessary that the centres of planetary movements are like the earth, i.e., of a physical kind. In the long commentary on the *Metaphysics*, Averroes will reject the idea of non-physical centres outside the centre of the world.[15] With regard to Ptolemy's epicycle theory, however, Averroes was skeptical from the beginning of his scientific career. This is obvious from a side-remark in the *Epitome* of the *Metaphysics*, but also from his *Epitome* of the *Almagest*. The latter text dates to ca. 1159–1162, i.e. roughly the same early period as the *Epitome* of the *Metaphysics*. In the *Epitome* of the *Almagest* Averroes clearly states that the mathematical astronomers in the Ptolemaic tradition hold theories that 'for the most part are not possible; this must be so in the case of the epicycle,' since the epicycle is in conflict with the principle of natural science according to which for such a movement one needs a (physical) centre. Nevertheless, Averroes says, he will, in this treatise on the *Almagest*, concentrate on the astronomy as it is commonly accepted, since there is no demonstrative astronomy. He hopes to do research on the topic in the future.[16]

In contrast to al-Biṭrūǧī, Averroes was not an astronomer in the mathematical sense. Even his *Epitome* of the *Almagest* is a work with only few numbers. It is nevertheless clear that the project of a radically new astronomy was dear to his heart. Averroes had a particular view of the history of astronomy up to his time. In the long commentary of the *Metaphysics*, Averroes tells his readers that the ancient astronomers before Hipparchus and Ptolemy did not posit eccentrics and epicycles, but instead posited 'spiral motions.' Ptolemy then rejected spiral motions, Averroes says, because he believed that the number of motions would be increased in vain by postulating the existence of spiral motions. Under the influence of Ptolemy, readers of Aristotle were not able to understand what Aristotle says about the astronomy of his predecessors on which he relied – and which is the true astronomy. Hence, for Averroes, the science of astronomy saw a decline after Aristotle, and Ptolemy was partially responsible for it.[17]

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[14] See Arnzen's introduction to Averroes, *On Aristotle's* Metaphysics, 11.

[15] Averroes, *On Aristotle's* Metaphysics, 148, with Arnzen's commentary on 312–313, and the slightly diverging interpretation by Sabra, 'The Andalusian Revolt,' 140.

[16] Lay, 'L'*Abrégé* de l'Almageste,' 52–55.

[17] Averroes, *Tafsīr mā ba'd al-ṭabī'a*, comm. XII.45, 1658–1665. The translation in Sabra, 'The Andalusian Revolt,' 141–142, is more reliable than that in Genequand, *Ibn Rushd's Metaphysics*, 176–179.

'Spiral motion' is a term Averroes encountered in the Arabic translation of Aristotle's *Metaphysics*: '*lawlabī*' ('screw-shaped,' 'spiral'). In other texts, such as *Physics* v.4 (228b24), the Arabic term '*lawlab*' translates the Greek ἕλιξ ('screw,' 'spiral').[18] As has been pointed out before,[19] Averroes here fails to understand Aristotle's point. Aristotle's idea was that one would need 'unrolling' or 'counteracting' spheres: σφαῖραι ἀνελιττούσαι (1074a2–3), which cancel out the movement of a sphere so that it does not distort the movement of the other spheres. The Greek 'ἀνελίττω' in other contexts means: to unroll a book, i.e. a papyrus roll.[20] The Arabic here reads: spheres '*allatī tadūru bi-dawr lawlabī*,' spheres 'which rotate with a spiral rotation.'[21] Averroes remarks that the passage in Aristotle's *Metaphysics* about the alleged 'spiral motion' is difficult to understand, and concludes:

> It is best to think of these spiral motions as resulting from opposite motions on different poles, for it thus happens that the star is seen to proceed sometimes forwards and sometimes backwards, sometimes quickly and sometimes slowly.[22]

What we have here is not Aristotle's idea of 'unrolling' or 'counteracting' spheres, but Averroes' and al-Biṭrūǧī's idea that the irregularities of the planetary movements ought to be explained by the addition of several movements of a sphere on different poles, which would then result in a spiral motion. Averroes here was the victim of Abū Bišr Mattā (d. 940), the Syriac-Arabic translator of book Lambda:[23] the term '*lawlabī*' was an unfortunate choice, which made it very difficult to understand Aristotle's original intention. It was a productive mistranslation, since it gave historical credit to Averroes' and al-Biṭrūǧī's idea that spiral motions, rotations of poles around poles, should be the backbone of a new, physical astronomy.

It turned out to be difficult to transport the concept of spiral motion into Latin. Michael Scot chose the phrasing '*sphaerae ... quae revolvuntur gyrative*,' when

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[18] See M. Ullmann, *Wörterbuch der Klassischen Arabischen Sprache*, II.3, Wiesbaden: Otto Harrassowitz, 2000, 1796, s.v. '*lawlabī*.' See also the entry '*lawlab*' on 1794–1796.

[19] Genequand, *Ibn Rushd's Metaphysics*, 54–55.

[20] See H.G. Liddell, R. Scott & H.S. Jones, *A Greek-English Lexicon*, Oxford: Clarendon Press, ^{9}1940, 131.

[21] Averroes, *Tafsīr mā baʿd al-ṭabīʿa*, comm. XII.47, 1669^{7}.

[22] Averroes, *Tafsīr mā baʿd al-ṭabīʿa*, comm. XII.47, 1674^{10}–1675^{1}. The translation is from Genequand, *Ibn Rushd's Metaphysics*, 183.

[23] On Abū Bišr Mattā's translation see A. Bertolacci, *The Reception of Aristotle's* Metaphysics *in Avicenna's Kitāb al-Šifāʾ: A Milestone of Western Metaphysical Thought*, Leiden [etc.]: Brill, 2006 (Islamic philosophy, theology, and science, 63), 5–35.

translating the sentence 'spheres ... which rotate with a spiral rotation' into Latin.[24] In other passages of book Lambda, Michael Scot translates *'lawlab'* again with *'gyrativus'* or *'gyratio,'* but once he uses the transcription *'laulab,'* which in the Latin transmission was soon corrupted into *'lenliab.'*[25] In his translation of Averroes' long commentary on *De caelo*, Michael Scot writes *'laulab.'*[26] Both *'gyrativus'* and *'laulab'* are unfortunate translations, because they do not convey the meaning 'spiral.'[27]

It remains unclear how an astronomy of spiral motion, as envisaged by Averroes, could be worked out mathematically. It would be rash to conclude, however, that Averroes 'was a poor scientist.'[28] Such a judgement is in line with what some historians of science have said about al-Biṭrūǧī, who 'heaps chaos upon confusion' and was not capable of 'serious planetary theory,' being not more than a philosopher.[29] Or as one historian put it: 'There is no doubt that al-Biṭrūjī deserves to be flunked.'[30] In fact, we do not know how convincing Averroes' astronomy would have been if he had found the time and the concentration for it. Averroes certainly was a serious scientist in other fields. It testifies to his scientific quality that his arguments against Ptolemy's astronomy are, as we shall see, both serious and historically influential.

The main arguments which Averroes advances against Ptolemy in the long commentary on the *Metaphysics* are two. First: an epicyclic sphere, that is, a sphere rotating on a larger eccentric cycle, is impossible since a body which moves circularly has to move around a centre; in the case of an epicycle, a centre would exist which is different from the centre of the universe, that is: 'there would exist an earth other

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[24] For the Latin, see Averroes, *In* Metaphysicam, 331^{rb}E.

[25] Averroes, *Tafsīr mā ba'd al-ṭabī'a*, comm. XII.45, 1662^{8,13}. For the Latin, see Averroes, *In* Metaphysicam, 329vaI: *'motus lenliab.'* This reading is found in 7 Latin manuscripts and many Renaissance editions of the text; most other manuscripts (of a total of 47) read *'vitium'* instead of *'lenliab.'*

[26] Averroes, *Commentum magnum super libro* De celo et mundo, II.35, 332^{74} ('motus qui dicuntur laulab') and 332^{77} ('moveantur super linea leulebie'). The term *'leulebie'* perhaps is a corruption of *'laulabi,'* a transcription of the adjective *'lawlabī.'* For the Arabic, see Averroes, *Commentary on Aristotle's Book on the Heaven and the Universe: Sharḥ kitāb al-samā' wa-l-'ālam*, 210^{24} and 211^{1}.

[27] The adjective *'gyrativus'* means 'circular' or 'turnable,' without any connotation of three-dimensionality. Cf. the entries on *'gyrativus'* in O. Prinz, *et al.*, *Mittellateinisches Wörterbuch bis zum ausgehenden 13. Jahrhundert*, München: Bayerische Akademie der Wissenschaften, 1967–, and D.R. Howlett, *et al.*, *Dictionary of Medieval Latin from British Sources*, Oxford: Oxford University Press, 1975–. Better choices would have been the nouns *'spira'* ('spiral') or *'cochlea'* ('snail'), or adjectives derived from them.

[28] Genequand, *Ibn Rushd's Metaphysics*, 54.

[29] E.S. Kennedy, 'Alpetragius's Astronomy,' *Journal for the History of Astronomy*, 4 (1973), 134–136.

[30] Sabra, 'The Andalusian Revolt,' 137.

than this earth,' *alia terra extra istam*, as Michael Scot translates.[31] In the long commentary on *De caelo*, chapter 1.5, Averroes gives a similar formulation to this argument: the heavenly bodies have a simple, non-composed movement, and a simple movement can only be circular around a centre or directed towards a centre. Hence, an epicycle needs a real centre.[32] The second argument runs as follows: also a simple eccentric sphere (a deferent) is impossible. Because then there would be an empty space between the celestial bodies, and since a vacuum is impossible, one would need to postulate the existence of heavenly bodies whose sole purpose would be to fill in the empty space.[33]

In what follows, I shall inquire into the extent to which these arguments influenced the commentary tradition on *Metaphysics* Lambda in the Latin speaking world. Edward Grant, in the footsteps of a pioneering study by Pierre Duhem, has translated and analysed the reception of Averroes' arguments by the scholastic authors Bernard of Verdun, in the late thirteenth, and John Buridan, in the fourteenth century.[34] I shall briefly touch upon these authors, and upon Albert the Great and Thomas Aquinas. But my focus will be on two Latin experts on Averroes, John of Jandun (d. 1328) and Agostino Nifo (d. 1538), who offer detailed interpretations of Averroes' critique of Ptolemy, but come to very different conclusions.

Albert the Great, in his *Metaphysics* commentary of ca. 1262, confuses the historical sequence of astronomers. He erroneously attributes the eccentric theory to

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[31] Averroes, *Tafsīr mā ba'd al-ṭabī'a*, comm. XII.45, 1661. For the Latin, see Averroes, *In* Metaphysicam, 329vaH.

[32] The Arabic of this passage is not extant. For the Latin, see Averroes, *Commentum magnum super libro* De celo et mundo, 1.5, 1: 14–15. The passage concludes (15$^{94-95}$): 'Et ideo videmus quod epicicli quos ponunt astrologi falsi sunt, et forte similiter est de ecentricis <et> magis.'

[33] Averroes, *Tafsīr mā ba'd al-ṭabī'a*, comm. XII.45, 1661–1662. For the Latin, see Averroes, *In* Metaphysicam, 329vaH: 'Et similiter forte est de ecentrico quem ponit Ptolemeus ...' The argument appears also in the long commentary on *De caelo*, chapter II.35; see the references in n. 12 above.

[34] Duhem, *Le système du monde*, 3: 241–498; E. Grant, *A Source Book in Medieval Science*, Cambridge (MA): Harvard University Press, 1974 (Source books in the history of the sciences), 516–529. See also Claudia Kren's studies on Henry of Langenstein's contribution to the debate: C. Kren, 'Homocentric Astronomy in the Latin West: The *De reprobatione ecentricorum et epiciclorum* of Henry of Hesse,' *Isis*, 59 (1968), 269–281; and Ead., 'A Medieval Objection to "Ptolemy,"' *The British Journal for the History of Science*, 4 (1969), 378–393. For context, see H. Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West,' in: R. Rashed (ed.), *Encyclopedia of the History of Arabic Science*, 3 vols, London [etc.]: Routledge, 1996, 1: 284–305, esp. 294–296.

Calippus, the contemporary of Aristotle. The influence of Averroes' comments is only felt in that Albert shows an awareness of the fact that the epicycle-eccentric theory is disputed. Albert argues that the critique of the eccentric and epicycle theory is not well founded, because it is based on the assumption that all celestial bodies share the same nature, the fifth elementary nature, and that hence they need to have the same motion. But the corporeal nature of the celestial bodies in fact varies, Albert argues, which is why their movement varies. Albert does not want to settle the astronomical problem. He writes:

> We do not approve or disapprove of the theory of eccentrics and epicycles, but we will show in what follows that the celestial bodies have every movement that the moving intelligence needs for producing the forms it has in matter.[35]

In other works by Albert, there is further evidence for his rejection of al-Biṭrūǧī's and Averroes' astronomical positions, especially in the commentary on *De caelo*. Among the arguments employed by Albert are also empirical ones, such as that the diameter of planets appears sometimes shorter, sometimes longer. The variation of the diameter would not be observable in a strictly concentrical cosmos, where the planets always keep the same distance to the earth; and hence Averroes' theory is mistaken: *Averroes errat graviter*.[36]

Thomas Aquinas' commentary on Aristotle's *Metaphysics* dates to ca. 1270–1272. For him, book Lambda is the twelfth book of the *Metaphycics*, and not the eleventh, as in the Arabic tradition – which shows that he uses William of Moerbeke's new Greek-into-Latin translation of Aristotle's *Metaphysics*.[37] Thomas contends that Ptolemy follows the theory of the Pythagoreans, who explained the irregularities of the planetary movements by stating that the planets move in eccentric spheres and

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[35] Albertus Magnus, *Metaphysica*, II.3.2, ed. B. Geyer, Münster: Aschendorff, 1964 (Opera omnia, 16/2), 535^{33-38}: 'Nos autem sententiam de excentricis et epicyclis nec approbamus nec improbamus, sed in sequentibus ostendemus quod corpora caelestia omnem motum habent qui intelligentiae moventi debitus est ad hoc quod formas quas habet producat in materiam.' Cf. also chapters II.2.22–24 of the *Metaphysica*, where Albertus discusses the astronomical theories of Calippus, Eudoxus, Ptolemy, al-Biṭrūǧī, and Maimonides (Albertus, *Metaphysica*, 510–514).

[36] Albertus Magnus, *De caelo et mundo*, II.3.8, ed. P. Hossfeld, Münster: Aschendorff, 1971 (Opera omnia, 5/1), 160. For further evidence see Duhem, *Le système du monde*, 3: 327–345.

[37] See G. Vuillemin-Diem, 'Praefatio: Wilhelm von Moerbekes Übersetzung der Aristotelischen Metaphysik,' in: Aristoteles Latinus, *Metaphysica lib. I–XIV: Recensio et Translatio Guillelmi de Moerbeka*, ed. G. Vuillemin-Diem, 1, Leiden [etc.]: Brill, 1995 (Aristoteles latinus, 25.3/1), 257.

in small circles, which they call epicycles.[38] Thomas then puts forward arguments against this position, which are all drawn silently from Averroes: the Pythagorean-Ptolemaic theory is in conflict with the proven principles of natural science. All movement is related to the centre of the world. One would have to assume a void between the spheres to make room for the eccentric sphere or, alternatively, to postulate the existence of unmoved bodies in the empty space. The sphere through which the epicycle moves, could not be solid, but would have to be divisible. And Thomas continues:

> But all these things are against what has been proven in natural science. To avoid them, Eudoxus, who was aware of this, posited for each planet several spheres that have the earth as their centre.[39]

Since Thomas does not mention Averroes as the source of these arguments, the reader is led to assume that, anachronistically, Eudoxus himself was aware of these deficiencies of the Pythagorean epicycle theory. Thomas transports Averroes' arguments backwards in history to support Eudoxus' and hence, indirectly, Aristotle's position. Thomas does not have any difficulties in understanding Aristotle's concept of 'unrolling' spheres, since he has read both Michael Scot's and William of Moerbeke's translations. Where Michael Scot had written *'sphaerae quae revolvuntur girative'*, William of Moerbeke (and with him Thomas) writes: *'sphaerae revolventes'*. Thomas understands that Aristotle adds these spheres in order to cancel out the motion of a preceding sphere.[40] Albert the Great and Thomas Aquinas therefore arrive at very different conclusions. For Albert, the opponents of the epicycle theory do not have convincing arguments. Thomas Aquinas, in contrast, shows open sympathies for Averroes' position: he adopts his arguments[41] and attributes them to the proto-Aristotelian astronomer Eudoxus. Thomas does not, however, engage with Averroes' ideas about spiral motion.

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[38] Thomas Aquinas, *In duodecim libros* Metaphysicorum *Aristotelis expositio*, XII, l. 10, ed. M.-R. Cathala & R.M. Spiazzi, Torino [etc.]: Marietti, 1950, 601, n. 2567.

[39] Thomas Aquinas, *In libros* Metaphysicorum, 601, n. 2570: 'Sed tamen omnia huiusmodi sunt contra ea quae determinata sunt in scientia naturali. Unde ad haec evitanda Eudoxus hoc videns posuit cuique planetae sphaeras plures concentricas mundo.'

[40] Thomas Aquinas, *In libros* Metaphysicorum, 602, n. 2580.

[41] The *Metaphysics* commentary contains Thomas Aquinas' most outspoken rejection of Ptolemaic astronomy. In other texts, his position is much more concialiatory, as has been shown by Th. Litt, *Les corps célestes dans l'univers de Saint Thomas d'Aquin*, Leuven: Publications Universitaires – Paris: Béatrice-Nauwelaerts, 1963 (Philosophes médiévaux, 7), 342–366, esp. 361.

Let me briefly mention the positions of Bernard of Verdun and John Buridan. Bernard of Verdun, the late thirteenth-century author of a *Tractatus super totam astrologiam*, correctly describes Averroes' purpose: Averroes propagates an astronomy without eccentrics and epicycles by positing spheres that are moved on many poles with the effect of composed motions. But Bernard rejects this position and concludes that epicycles and eccentrics ought to be real.[42]

John Buridan, in his commentary on the *Metaphysics*, gives full room to Averroes' arguments, which he cites at length and under Averroes' name. His overall conclusion, however, is to follow Averroes only halfway: Buridan denies epicycles, but affirms eccentrics. He sides against Averroes and 'with Ptolemy and all modern astronomers' (*per Ptolemaeum et omnes astrologos modernos*),[43] because there is one irregularity in the movement of the heavens which cannot be explained without recourse to eccentrics: the varying distances of the planets to the earth. An eccentric sphere is not equidistant from the earth in all its parts, but is closer to the earth at one point and further away at another, Buridan argues. Eccentricity therefore can explain this irregularity, for which one does not need to assume the existence of epicycles. Averroes, Buridan says, has made attempts to find a different explanation, but was not successful, 'as he confessed'[44] – with this Buridan refers to Averroes' statement cited above that he has grown old without developing a new astronomical theory.

In what follows, I shall draw attention to a dispute about the correct interpretation of Averroes' critique of Ptolemy by two commentators on the *Metaphysics*: John of Jandun and Agostino Nifo. Nifo, the Paduan philosopher of the late fifteenth century, replies to the exposition of Averroes offered by John of Jandun, who lived two centuries earlier. Nifo, in fact, often castigates John of Jandun for misunderstanding Averroes, such as on the famous passages concerning the unicity of the intellect in the long commentary on *De anima*, chapter III.5, but also on several other issues.[45]

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[42] Bernard of Verdun, *Tractatus super totam astrologiam*, ed. P. Hartmann, Werl: Coelde, 1961 (Franziskanische Forschungen, 15). On Bernard, see Duhem, *Le système du monde*, 3: 442–460; Grant, *A Source Book*, 520–524; and Th. Glick, *et al.*, *Medieval Science, Technology, and Medicine: An Encyclopedia*, New York [etc.]: Routledge, 2005, s.v. 'Bernard of Verdun.'

[43] John Buridan, *In* Metaphysicen *Aristotelis quaestiones argutissimae*, XII, q. 11, Paris: Jodocus Badius, 1518 (repr. [with the wrong date 1588 on the titlepage] Frankfurt am Main: Minerva, 1964), 73^{vb}. The same expression appears in XII, q. 10, 73^{rb}.

[44] Buridan, *In* Metaphysicen *Aristotelis*, XII, q. 11, 74^{ra}: 'Et breviter Commentator laboravit ad salvandum istam apparentiam aliter et non potuit, ut confitetur.'

[45] See D.N. Hasse, '*Averroica secta*: Notes on the Formation of Averroist Movements in Fourteenth-Century Bologna and Renaissance Italy,' in: J.-B. Brenet (ed.), *Averroès et les*

It is noteworthy that the disagreement concerns also astronomical topics. This contrasts, for instance, with other philosophers of the Aristotelian tradition such as Francisco Suárez (d. 1617), who, in his *Metaphysicae disputationes*, passes by most of the astronomical material in *Metaphysics* Lambda, because he does not find it philosophically relevant.

The Master of Arts John of Jandun (d. 1327) worked on his *Metaphysics* commentary in Paris between 1318 and 1325, before he was forced to abandon the city due to charges of heresy.[46] In book XII of his commentary, Jandun discusses the question 'Whether there are several eccentric orbs and epicycles in the celestial bodies in reality' (*Utrum eccentrici orbes et epicycli sunt plures in corporibus coelestibus secundum naturam rei*). He begins by answering 'yes' on 'the authority of Ptolemy and all modern astronomers positing eccentrics and epicycles.'[47] The wording is similar to Buridan's, which suggests that Buridan may have been drawing on Jandun. Jandun gives a detailed account of Averroes' arguments, and exhibits a masterly knowledge of the many passages in Averroes' works in which eccentrics and epicycles are mentioned, especially in the commentaries on *De caelo* and the *Metaphysics*. He lists five arguments altogether: (1) If there existed eccentrics and epicycles, there would exist physical centres outside the centre of the earth and hence outside the centre of the world. Thus, one would have to assume the existence of several worlds, which is absurd. (2) The eccentric circle is closer to the earth at some point and more remote at another point. As a consequence, the vacuum that opens in the gap between the spheres would have to be filled with bodies that are useless otherwise – which is impossible. (3) If one does not concede the existence of a vacuum, the celestial bodies would have to travel through and penetrate another body. (4) If the celestial bodies had different centres, they would belong to different species of bodies. (5) The eccentric-epicycle theory has to concede that there exists a motion which is neither directed at a centre nor coming from a centre nor moving around a centre, since the centre of this motion would not be the centre of the world.[48]

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averroïsmes juif et latin. Actes du colloque international, Paris 16–18 juin 2005, Turnhout: Brepols, 2007 (Textes et études du moyen âge, 40), 307–331, at 324–331.

[46] For an up-to-date biography of John of Jandun see J.-B. Brenet, 'John of Jandun,' in: H. Lagerlund (ed.), *Encyclopedia of Medieval Philosophy. Philosophy between 500 and 1500*, Dordrecht: Springer, 2011, 1: 626–629.

[47] John of Jandun, *Quaestiones in duodecim libros* Metaphysicae, XII, q. 20, Venezia: Hieronymus Scotus, 1553 (repr. Frankfurt am Main: Minerva, 1966), 141ra: 'Et arguitur primo quod sic auctoritate Ptolomei et omnium astronomorum modernorum ponentium eccentricos et epicyclos.'

[48] John of Jandun, *In libros* Metaphysicae, XII, q. 20, 141$^{rb–va}$.

Jandun presents justifications for all five arguments. He then introduces his conclusion by differentiating between two possible interpretations (*imaginationes*) of the eccentric-epicycle theory. He first describes these interpretations with respect to eccentrics and then turns to epicycles:

> It also has to be noted that there are two ways in which we can understand (*imaginari*) (the theory) that the epicycles are in the celestial bodies. (1) One way is that half of the epicycle is outside the extreme surface of the deferent (circle) and half of it inside. This (version of the theory) is impossible, since it would necessarily entail the above-mentioned absurdities, because the first half (of the epicycle) would reach outside the extreme surface of the deferent, and if it moved, it would have to come to a place where there was a vacuum or a plenum before, as is obvious to those who study the descriptions below. If a vacuum, it would not move outside the extreme surface of the deferent because, if there existed a vacuum, there would not exist movement, as stated by Aristotle in the fourth book of the *Physics*. If a plenum, there would occur a penetration of dimensions. The Commentator presumably disproved the epicycles this way according to this false understanding (*falsam imaginationem*). (2) The other way is that the whole epicycle is within the extreme surface of the deferent which carries the planet, so that the epicycle is in the depth of the deferent. Hence, the deferent circle needs to have such a depth that it can receive and comprise the entire epicycle and its diameter, and that the epicycle moves in its depth around its own centre. In this latter way these epicycles are possible.[49]

This conclusion is formulated again in a brief paragraph at the end of the *quaestio*: Averroes' arguments hold only against the first understanding of the epicycle theory,

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[49] John of Jandun, *In libros* Metaphysicae, XII, q. 20, 141^{va-vb}: 'Notandum etiam epicyclos esse in corporibus coelestibus possumus imaginari dupliciter. Uno modo quod medietas epicycli sit ultra superficiem extremam deferentis planetam et medietas intra. Et hoc modo est impossibile, quia tunc de necessitate sequerentur dicta inconvenientia, quia illa medietas elevaretur super extremam superficiem deferentis et, cum moveretur, oporteret devenire ad locum ubi prius fuit vacuum vel plenum, ut patet inspicienti descriptiones inferius. Unde etiam si esset vacuum ibi, tunc illa medietas extra superficiem deferentis extremam non moveretur, quia in vacuo, si esset, non esset motus, ex quarto *Physicorum*. Sed si inveniretur plenum, tunc ibi fieret penetratio dimensionum. Et hoc modo forte improbavit Commentator epicyclos secundum istam falsam imaginationem. Alio modo possumus imaginari quod totus epicyclus sit inter superficiem extremam deferentis planetam, ita quod in profunditate eius sit, ita quod oportet ipsum deferentem circulum habere tantam profunditatem quod possit recipere et comprehendere totum epicyclum et diametrum eius, et quod moveatur in profunditate eius circa centrum suum; et hoc modo circuli isti epicycli sunt possibiles.'

Jandun argues, because then the spheres would not be contiguous; they do not hold against the second understanding.[50]

The ultimate source of this passage, or rather the source of the second and true understanding of epicycle theory, is Ptolemy himself. In the *Planetary Hypotheses*, Ptolemy gives a physical interpretation of the astronomy of the *Almagest*. Eccentrics and epicycles are now described as three-dimensional, solid spheres, and not as two-dimensional circles, as in the *Almagest*. The epicycle spheres are nested within the deferent spheres. The planetary distances from the centre of the earth are always such that the minimum distance of a planet is equal to the maximum distance of the next lower planet, so that the two spheres never interfere. Ptolemy discusses the planetary distances in detail, and also advances a biological interpretation of the universe: the celestial spheres have souls, which move themselves.[51] Ptolemy's system of nested spheres was embraced by many Arabic writers, often without the biological cosmology. The medieval Latin world also got to know of it, but not through Ptolemy's *Planetary Hypotheses* themselves. Of this treatise, only the first part survives in Greek; the whole text is extant in Arabic and in a Hebrew translation from the Arabic; a medieval Latin version does not seem to exist. Instead, Ptolemy's cosmological system reached the Latin West by way of at least two other channels: first through al-Farġānī's *Kitāb Ǧawāmiʿ ʿilm al-nuǧūm* (*Book of the Summaries of the Science of the Stars*), which is a non-mathematical digest of the *Almagest* that incorporates the nested-spheres cosmology. It was twice translated into Latin in the twelfth century. And second through Ibn al-Haytam's *Maqāla fī hayʾat al-ʿālam* (*On the Configuration of the World*), which was translated into Latin in the twelfth or thirteenth century.[52] Ibn al-Haytam does not quote the *Planetary Hypotheses* and does not use its planetary distances,[53] but the cosmology he presents, according to which eccentrics are embedded in concentric spheres and epicycles within eccentric spheres, is clearly inspired by Ptolemy's system of nested spheres.[54]

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[50] John of Jandun, *In libros* Metaphysicae, XII, q. 20, 142[ra]: 'Ad rationes Commentatoris patet ex dictis quod procedunt de istis orbibus secundum imaginationem primam, scilicet non sunt contigui. Sed si ponuntur secundo modo, nihil concludunt contra hos orbes, ut visum est.'

[51] See the references in n. 3 above.

[52] A modern Latin edition (or rather: transcription of a manuscript) of Ibn al-Haytam's treatise is found in J.M. Millás Vallicrosa, *Las traducciones orientales en los manuscritos de la Biblioteca Catedral de Toledo*, Madrid: Consejo superior de investigaciones cientìficas, 1942, 285–312.

[53] As pointed out by T. Langermann, *Ibn al-Haytham's* On the Configuration of the World, New York [etc.]: Garland, 1990, 11–25.

[54] See Sabra, A.I., 'Configuring the Universe: Aporetic, Problem Solving, and Kinematic

Among the earliest Latin recipients of this theory was Roger Bacon, as Pierre Duhem has shown.[55] In his *Opus tertium*, which was written in Paris in the 1260s, Bacon relates Averroes' arguments against the eccentric and epicycle theory, without mentioning Averroes: Ptolemy's theory jeopardizes the concentricity of the cosmos and has to concede the existence of a vacuum or the existence of two bodies in one place.[56] Bacon then proceeds to discuss the conception of the problem by some modern scholars (*quaedam imaginatio modernorum*), in defense of Ptolemy's position. The 'modern understanding' presented by Bacon is the nested-spheres theory. Duhem had already surmised that Ibn al-Haytam was the source of Bacon's 'understanding of the moderns.'[57] And, indeed, Bacon's vocabulary clearly indicates that he is drawing on Ibn al-Haytam's newly translated *On the Configuration of the World*: the spheres have one '*superficies convexa*' and one '*concava*' (a convex and a concave surface); the epicycle is '*infixus*' (inserted) in another sphere with '*superficies equidistantes*' (equidistant surfaces), in the middle of the '*spissitudo*' (depth) of the sphere; the eccentric sphere is '*deferens secum*' (carrying with it) the epicyclic sphere, and the planet '*movetur*' (is moved) with it.[58] It is noteworthy that the Latin reception of the nested-spheres theory was critical from the beginning; Bacon here sets the tone. He finds it in conflict with, among other things, the observation that the moon always shows the same side to the earth. This can only be explained by the un-Aristotelian assumption that the moon moves around its own centre or by demanding the concentricity of the spheres.[59] It was important, however, that Bacon was not willing to embrace al-Biṭrūǧī's and Averroes' concentric astronomy either. He offers empirical arguments in favour of Ptolemy's theory, among them the

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Modeling as Themes of Arabic Astronomy,' *Perspectives of Science*, 6 (1998), 288–330, repr. in: P.E. Pormann (ed.), *Islamic Medical and Scientific Tradition: Critical Concepts in Islamic Studies*, London [etc.]: Routledge, 2011, 3: 95–134, esp. 101–102 (and nn. 10 and 12).

[55] P. Duhem, *Un fragment inédit de l'*Opus tertium *de Roger Bacon, précédé d'une étude sur ce fragment*, Quaracchi: Collegium S. Bonaventurae, 1909; Id., *Le système du monde*, 3: 420–442. Roger Bacon's important contribution to astronomical cosmology is strangely absent in J.M.G. Hackett (ed.), *Roger Bacon and the Sciences: Commemorative Essays*, Leiden [etc.]: Brill, 1997 (Studien und Texte zur Geistesgeschichte des Mittelalters, 57).

[56] Duhem, *Un fragment inédit*, 119–125.

[57] For further evidence of Ibn al-Haytam's influence on Latin astronomy, see J.L. Mancha, 'Ibn al-Haytham's Homocentric Epicycles in Latin Astronomical Texts of the XIVth and XVth Centuries,' in: J.L. Mancha, *Studies in Medieval Astronomy and Optics*, Aldershot: Ashgate, 2006 (Variorum collected studies series, 852), art. VIII.

[58] The vocabulary appears both in Ibn al-Haytam, *On the Configuration of the World*, ed. Millás Vallicrosa, 300, and Roger Bacon, *Opus tertium*, edited in Duhem, *Un fragment inédit*, 125 and 128–129.

[59] Duhem, *Un fragment inédit*, 132–133.

non-uniformity of the planetary motions (*inuniformitas motus planetarum*) and the varying distances of the same planet towards the earth. The influence of these arguments can be seen in Bernard of Verdun and John Buridan. Bacon thus offered arguments for either side, without ending the discussion with a proper conclusion.[60]

It is very likely that John of Jandun's distinction between two '*imaginationes*' of the epicycle theory is another echo of Roger Bacon's *Opus tertium*. But while Bacon accuses the nested-sphere cosmologists to be ignorant of proper Ptolemaic astronomy, Jandun welcomes the interpretation. In his view, the epicycle and eccentric theory is justified if interpreted as a system of nested spheres. On the other hand, Jandun argues, Averroes was right with his criticism of Ptolemy, since his arguments are conclusive when directed against a cosmology in which the movement of the epicycles reaches outside the deferent sphere. Jandun's obvious aim was to rescue both Ptolemy and Averroes.

When in the late fifteenth century Agostino Nifo (d. 1538) read John of Jandun's exposition of Aristotle's book Lambda, he did not agree. Among Nifo's earliest works is a commentary on book Lambda of the *Metaphysics*, which was written at Padua University in 1497, when Nifo was professor of philosophy concurrent with Pietro Pomponazzi.[61] The text is a commentary both on Aristotle and on Averroes. When commenting on Averroes' commentary 45, Nifo attacks Jandun directly:[62]

> You have to know that John of Jandun fancies (*fingit*) that Averroes negates these (epicyclic and eccentric) bodies in one way and concedes them in another way, and John tries to interpret these ways. But this person certainly did not understand what Averroes meant. For Averroes everywhere takes pains to destroy these (bodies) completely and attempts to save the phenomena by way of concentric orbs of the world and through the diversity of motions upon different poles, as it was popular in the time of Aristotle. And he saves everything, as he says, through the line 'lenlab' (*omnia salvat ... per lineam lenlab*), except for what appears of the eclipses. And therefore John of Jandun, while attempting to save Averroes, destroys him.[63]

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[60] Duhem, *Un fragment inédit*, 131–137.

[61] On Nifo's life and works, see Ch. Lohr, *Latin Aristotle Commentaries*, II: *Renaissance Authors*, Firenze: Olschki, 1988 (Corpus philosophorum medii aevi. Subsidia, 6), 282–287.

[62] The passage reappears in the same wording in Nifo's *Expositiones in Aristotelis libros* Metaphysices, which were composed in the last years before his death in 1538. Nifo does not say much on the topic in his third metaphysical work, the *Dilucidarium metaphysicarum disputationum in Aristotelis libros* Metaphysicorum of 1510.

[63] A. Nifo, *In XII* Metaphysices *Aristotelis et Averrois volumen*, Venezia: Octavianus Scotus, 1518, 29^{rb} (= A. Nifo, *Expositiones in Aristotelis libros* Metaphysices, Venezia: Hieronymus

From Jandun's perspective, Averroes' arguments are strong, but only hold against a specific interpretation of Ptolemy, which does not integrate the idea of nested spheres. Nifo, in turn, rightly criticizes that Averroes does not draw the distinction between two different interpretations of the eccentric and epicycle theory, and that Averroes' true intention is the radical rejection of Ptolemaic astronomy and the return to concentric spheres. Nifo explains that Averroes' strongest argument is that the whole and the parts of the universe have to have the same centre, and that nothing helps against this argument.

Interestingly, Jandun had seen this reply coming: he believes that Averroes wanted to argue only against a specific interpretation of Ptolemy's theory, but he concedes that Averroes' 'words do not have this appearance, because the wording seems to indicate that Averroes wanted to remove these spheres entirely (*simpliciter*).'[64] Jandun admits that his interpretation does not take Averroes' words at face value. He turns Averroes into a reformer of Ptolemaic astronomy, while Nifo sees him as a revolutioner. Nifo comes closer to the historical truth. As has been shown recently, Averroes was very well aware of the nested-spheres interpretation of the Arabic *hay'a*-Tradition since his early *Epitome* of the *Almagest*. He was even acquainted with Ibn al-Haytam's *On the Configuration of the World* and *Doubts*.[65] But, as was pointed out above, Averroes was skeptical about the existence of epicycles from the very beginning. In this regard, he differed much from Ibn al-Haytam: he did not demand a reform of the Ptolemaic system, but its replacement.

Nifo's second line of criticism is directed against Jandun's alleged ignorance of Averroes' theory of '*lenliab*,' that is, in Michael Scot's translation: of '*laulab*' or '*gyratio*,' which translate the Arabic '*lawlab*' ('spiral motion'). Nifo rightly insists that this is the core idea of Averroes' astronomical theory. In fact, Jandun, for all his detailed exposition of Averroes' arguments, does not mention '*laulab*' or '*motus*

Scotus, 1559 [repr. Frankfurt am Main: Minerva, 1967], comm. 45, 579[b]): 'Debes scire quod Ioannes Iandonus fingit negare haec corpora Averroem uno modo et concedere alio modo, et conatur exponere illos modos. Sed iste homo certe non habet mentem Averrois, nam Averroes ubique nititur destruere haec omnino et conatur salvare (ed. 1559: salutare) apparentias per orbes concentricos mundi et per diversitatem motuum supra diversis polis ut erat tempore Aristotelis famosum. Et omnia salvat, ut dicit, per lineam lenlab, excepto illo quod apparet de eclipsibus. Et propterea Ioannes quaerens salvare Averroem destruit ipsum.' The expression '*linea lenlab*' derives from the *De caelo* commentary; cf. n. 26 above.

[64] John of Jandun, *In libros* Metaphysicae, XII, q. 20, 142[ra]: 'Modo forte Commentator intendit arguere contra illos qui primo modo imaginabantur eccentricos orbes et epicyclos, ut patuit, sed hoc non videntur praetendere verba eius, quia videtur ex verbis eius quod simpliciter Commentator intendat removere orbes illos.'

[65] Lay, 'L'*Abrégé* de l'Almageste,' 42–45.

gyrativi' at all when discussing the eccentric and epicycle theory in *quaestio* 20 of his commentary on book Lambda. It may well be, however, that the reason for this silence is the problematic textual tradition of the passage in Latin. For in many manuscripts of the *Metaphysics* commentary the terms '*gyrativi*' and '*gyratio*' ('spiral') are corrupted into '*generativi*' and '*generatio*' ('generation'). Also, the transcription '*laulab*,' which Michael Scot had used once in the *Metaphysics* commentary, was often subject to corruption in the Latin manuscript transmission. In view of this, it may have been a wise choice on Jandun's side not to discuss Averroes' theory.

Nifo himself was struggling with these textual problems. The text he was using reads '*generatio*' instead of '*gyratio*.' Nifo tries his best to make sense out of a corrupt text:

> Now Averroes explains Ptolemy's error. He means that Ptolemy ignored the basic principle (*fundamentum*) of the ancient thinkers, by which they posited the movement of multiplication, that is, multiplication by generating (*generando*) many movements.[66]

Hence, in this passage, Averroes' idea of a spiral motion is transformed into an unspecific principle which generates many movements. This is a misunderstanding, but, with the help of Averroes' *De caelo* commentary, Nifo managed to unearth at least one part of Averroes' theory, namely the idea that planetary movements can be explained as rotations around several different poles (*circa varios polos*)[67] – which is a reflection of al-Biṭrūǧī's and Averroes' original concept of poles rotating around other rotating poles.

To conclude: Averroes' arguments certainly fell on fertile ground in the Latin West. The arguments themselves were well understood, and some authors, such as Thomas Aquinas and Agostino Nifo, were convinced by them, with the result that they were outspokenly critical of Ptolemy's astronomy. Other scholastics, such as John of Jandun and John Buridan, accepted large parts of Averroes' argumentation, but nevertheless tried to find a compromise position that rescued the Ptolemaic system. Still others, such as Albert the Great and Bernard of Verdun, rejected Averroes'

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[66] Nifo, *In XII* Metaphysices *Aristotelis et Averrois volumen*, 29^{rb} (= Nifo, *Expositiones*, 579ra): 'Nunc declarat errorem Ptolomei et vult quod Ptolomeus ignoret fundamentum antiquorum quo ponebant motum multiplicationis, idest, multiplicabant generando plures motus.'

[67] Nifo, *In XII* Metaphysices *Aristotelis et Averrois volumen*, 29^{rb} (= Nifo, *Expositiones*, 579ra).

arguments and maintained the physical reality of eccentrics and epicycles. It was one aim of this paper to show that this discussion was not confined to textual genera of astronomy and natural philosophy, but also entered the commentary tradition on Aristotle's *Metaphysics* for a long period. Some commentators on the *Metaphysics* even embarked on detailed discussions of astronomical theories. This is largely due to the influence of Averroes.

At the same time, Averroes' arguments were facing heavy contrary winds. From Albert the Great and Roger Bacon onwards, an array of empirical arguments was advanced against Averroes' critique, which invalidated the latter's position in the discussion. Moreover, the partisans of Ptolemaic astronomy received much support from the nested-spheres cosmology, which offered a model of how to interpret the Ptolemaic system physically. John of Jandun's commentary on Lambda is a witness to this development: Jandun acknowledges the strength of Averroes' arguments, but argues that they do not hold against a nested-spheres interpretation of Ptolemy's astronomy. The medieval Latin commentators were not aware of the fact that such an interpretation ultimately derived from Ptolemy's *Planetary Hypotheses*, but they apparently smelled its compatibility with Ptolemy's astronomy. The nested-spheres theory reached the Latin West mainly through Ibn al-Haytam's treatise *On the Configuration of the World*, which was translated into Latin in the twelfth or thirteenth century. That Ibn al-Haytam was the main channel of influence, is clearly indicated by verbal parallels between *On the Configuration of the World* and Roger Bacon's *Opus tertium* (of the 1260s), which in turn influenced several later authors. A later representative of this tradition was Georg Peurbach's influential textbook *Theoricae novae planetarum* of the 1450s.[68]

In the history of medieval cosmology, John of Jandun and Agostino Nifo occupy a special place. They count among the most dedicated and productive Latin admirers of Averroes as a philosopher and commentator. Their knowledge and understanding of Averroes' cosmology much surpasses that of their fellow commentators treated in this survey. To be sure, even Agostino Nifo, a champion of Averroes exegesis, was not able to make much sense of Averroes' beloved project, the spiral motion theory, for two reasons: because Averroes himself had only given a sketchy account of this idea, and because of textual problems. Michael Scot's term *'gyrativus'* ('circular'), in addition to often being corrupted into *'generativus,'* does not transport the meaning 'spiral' of the Arabic term *'lawlabī.'*

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[68] As argued by E.D. Sylla, 'Astronomy at Cracow University in the late Fifteenth Century: Albert of Brudzewo and John of Glogów', in: E. Jung (ed.), *What is New in the New Universities? Learning in Central Europe in Later Middle Ages (1348–1500)*. Proceedings of the XVIII[th] colloquium of the SIEPM, Łódź, 8–10 September 2011, forthcoming.

Despite these problems, Jandun and Nifo unearthed the full power of Averroes' arguments and thereby contributed to the criticism of Ptolemy in the Latin West. It has been pointed out before that, when Nicolaus Copernicus was studying at Cracow, Bologna and Padua, Averroes had reached a high point of popularity and that Averroes' critique of Ptolemy was much discussed in these universities, for instance by Albert of Brudzewo (d. 1495) in Cracow and Alessandro Achillini (d. 1512) in Bologna.[69] The case of Agostino Nifo is a further indication that there existed a current of intellectuals at Renaissance universities who, inspired by Averroes, openly rejected central features of Ptolemaic astronomy as untenable from a physical point of view.

[69] See P. Barker, 'Copernicus and the Critics of Ptolemy,' *Journal for the History of Astronomy*, 30 (1999), 343–358; M. Shank, 'Setting up Copernicus? Astronomy and Natural Philosophy in Giambattista Capuano da Manfredonia's *Expositio* on the *Sphere*,' *Early Science and Medicine*, 14 (2009), 290–315; and Sylla, 'Astronomy at Cracow University.'