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Albert the Great and the Arabic-Latin Reception of Euclid[1]

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Abstract: In Albert the Great's 13th century, a larger circulation of the complete Arabic-Latin translations of Euclid's *Elements,* done by Adelard of Bath, Robert Chester, and John of Tinemue begins to take place, alongside Gerald of Cremona's translation of Al-Nayrizi's *Commentary* on Euclid's *Elements*. The aim of this paper is to present how Albert the Great deals with the combination of these two traditions, i.e., the Arabic-Latin translations of Euclid and the Latin medieval geometrical practice.

Keywords: Albert the Great, Philosophy of Geometry, Euclid, Medieval Philosophy, Medieval Mathematics, Euclid's *Elements*.

[1] This article was translated by Fabiana Del Mastro, doctoral student in Philosophy at the Universidade de São Paulo. fabiana.mastro@usp.br.

It is very known Albert's criticism of Platonism with regard to the mathematical objects, which is based on the doctrine of the abstraction of the universal from sensitive individuals.[2] However, this theory must be understood under a specific perspective, once it is dependent on the so-called metaphysics of flow, a fundamental doctrine for the explanation of natural movement in Albert's physics[3]. The secondary literature agrees that the origin of this metaphysical discussion is in Avicenna[4]. The doctrine of flow is used to be restricted to the reception of the Avicennian doctrine of emanation[5] and to the reception of the *Liber de Causis*, which Albert saw as an Aristotelian work. Only in Thomas Aquinas' generation one will find out that the opuscule is an Arabic collection that has as source Proclus' theological doctrine.

In Albert, this doctrine is presented in detail in the commentary on the third book of the *Physics*[6]. Nonetheless, it can be observed that the relevance of the theory of flow is not restricted, as one might expect, to Albert's physics and metaphysics. Since it was a commonplace in the Latin medieval world that the notion of movement would be a subject restricted to the physics, mathematics should stick to the investigation of abstract and immovable entities.

However, Albert the Great and Roger Bacon's generation was largely influenced by the Persian mathematician and Arabic-speaking Al-Nayrizi[7], known as Anaritius among the Latins, who enabled the connection between the doctrine of flow and the mathematical practice. Although both authors, Albert the Great and Roger Bacon, had commented Euclid's *Elements*, influenced by Al-Nayrizi, only the first presents, in his philosophical work, a distinct view of the nature of the mathematical practice.

The commentary on Albert's Philosophy of Mathematics is mainly focused on determining the authors behind the Albertian expression *error platonis*. In an important article, Weisheipl attributes Albert's criticism, hidden behind such expression, to Robert Grosseteste, Roger Bacon, and Robert Kilwardby[8].

Nonetheless, the discovery, attribution of authorship, and edition of Albert the Great's *Commentary* on Euclid's *Elements* shed a new light on this investigation. Thus, the doctrine of flow, investigated in detail by Alain de Libera[9], could be used to explain Albert's mathematical theory. Al-Nayrizi, in turn, followed by Albert, genetically defines the mathematical objects from the initial notion of a flowing point. In this regard, from the perspective of the philosophy of mathematical practice, the possibility of use of mathematical genetic definitions dependent on movement and flow has not been carefully considered by the interpreters of Albert's criticism of the *error platonis*.

Alain de Libera was dedicated to fully analyze Albert the Great's metaphysics of flow[10] by linking this discussion to the reception of the Neoplatonic treatise *Liber de Causis*, which Albert understood as Aristotelian. The doctrine of emanation presented there was borrowed in order to explain the flow of

[2] Cf. ENDRISS, 1886, p. 85; cf. tb. TORRIJOS-CASTRILLEJO, 2015, p. 20.

[3] Cf. TWETTEN; BALDNER; SNYDER, 2013. p. 176.

[4] Cf. MCCULLOUGH, 1980; cf. also. MAIER, 1966; cf. also. LIBERA, 2005.

[5] This can be seen particularly in Avicenna's *Sufficientia*. Cf. MCCULLOUGH, 1980, p. 132ff; cf. also. MAIER, 1966.

[6] Cf. III *Physica*, I-III; ed. Colon. XXVII, 1993, p. 146ff.

[7] Al-Nayrizi's importance can be ensured due to the fact that his commentary on Euclid had been edited at the same time of Heiberg's standard edition of the *Elements,* in the 19th century, when Al-Nayrizi's edition was under Curtze's responsability, who took a bad manuscript as a basis. However, Tummers, who was in possession of more reliable manuscripts, was able to produce a new edition of Al-Nayrizi's commentary on the first four books of Euclid (cf. ANARITIUS; TUMMERS, 1994).

[8] Cf. WEISHEIPL, 1958.

[9] Cf. LIBERA, 2005, especially chapter IV.

[10] Cf. LIBERA, 2005, p. 143ff.

form in the substantial movement of generation. However, another reason to investigate the reception of Al-Nayrizi's commentary on Euclid's *Elements* consists in trying to map the path that made Albert use theses compatible with Neoplatonism in Philosophy of Mathematics, as, for example, the discussion on the role of imagination in the context of the geometrical practice.

Although he accuses his contemporaries of Platonism, from Plato's authorship Albert had access at most to a segment of Calcidius' translation of the *Timaeus*[11]. In addition, Albert's main Neoplatonic sources are Pseudo-Dionysius the Aeropagite and the very *Liber de Causis*, which play a fundamental role in the development of his thought[12]. In the case of the *Liber de Causis*, Albert sees it as an Aristotelian work, although it is a text with a Platonic inclination[13].

However, one notices an inclination to science in general and to the mathematical sciences in particular in Albert. For example, Ptolemy's *Almagest*[14] clearly had a significant influence over Albert's thought, for he shows a constant interest not only in geometry, but also in astronomy and perspective[15], which were studied in the Middle Ages as mathematical sciences. In fact, Albert probably wrote a commentary on the *Almagest*, as one can check in medieval catalogues[16]. Unfortunately, there is no known manuscript with the transmission of this work.

In the specific case of the commentary on Euclid, Albert wrote it before commenting the *Metaphysics*[17]. Nonetheless, when commenting Aristotle, a constant interest in relating the eventual mathematical examples used by the Stagirite with corresponding discussions on the Euclidian work is observed[18].

The Reception of Euclid's Work

The reception of Euclid's *Elements* is a special chapter in the History of Geometry. The main source of the Pre-Euclidian History of Geometry is Proclus, in his *Commentary* on the *Elements*. Proclus lived in the 5th century and was born around 700 years after Aristotle's death. Therefore, one understands the Latin confusion between Euclid of Alexandria, author of the *Elements*, and Euclid of Megara, one of Socrates' disciples. The narratives on Euclid of Alexandria's work are few, mainly based on a reference of his encounter with Pharaoh Ptolemy II, described in the second prologue to Proclus' *Commentary* on Euclid[19], where the dating comes from. Now, this text was only translated to Latin in 1533, in Simon Grynaeus' famous edition of the *Elements*[20]. It is also worth noting that Simplicius, who flourished in the beginning of the 6th century of our era, also made a commentary on the *Elements*, unfortunately lost.

In its turn, the Arabic-speaking intellectual tradition finds in the texts that circulated in the Byzantine Empire its main source for the transmission of the Greek philosophy and sciences to Prophet Muhammad's

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[11] Cf. CRAEMER-RUEGENBERG, 2005, p. 27; ANZULEWICZ, 2013; TORRIJOS-CASTRILLEJO, 2015, p. 20.

[12] Cf. ANZULEWICZ, 2013, p. 595-596.

[13] On the misunderstanding of the *Liber de Causis* as a work of Aristotle, despite the Platonism of its content, cf. LIBERA, 1992.

[14] Cf. *II De Caelo et Mundo*, III.6 (ed. Colon. V, 1971, p. 153ff.).

[15] Cf. GEYER, 1958, p.162.

[16] Cf. GEYER, 1958, p. 163.

[17] Cf. GEYER, 1958, p.162.

[18] Check, for example, the discussion presented in TUMMERS, 1984 with regard to Albert's *Commentary* on Aristotle's *Metaphysics*.

[19] In accordance with Proclus' narrative, when the pharaoh asked if there was an easier way to learn his science, Euclid answered that there was no real path to geometry. Cf. MORROW, 1992, p. 57.

[20] Cf. DE JESUS, 2019, p. 3.

language. Alexander of Aphrodisias, for example, was a distinguished and influent author both for Avicenna and Averroes, two of the most known Arabic philosophers.

With regard to the reception of Euclid, one must emphasize Al-Nayrizi's work, who became known among the medieval Latins as Anaritius. He lived between the second half of the 9th century and the beginning of the 10th century and wrote the important *Commentary* on the 10 first books of Euclid's *Elements*. We highlight two points here. Firstly, unlike Proclus, he does not limit himself to comment the first book. Secondly, Al-Nayrizi commonly refers to Simplicius, who in the Latin edition bears the name Sambelichius[21]. Apparently, there is no reference to Proclus, which enables us to speculate that Al-Nayrizi could have had Simplicius' lost work as his original source.

The main point to be emphasized in the Arabic reception of Euclid is the appreciation of the theory of flow, which Proclus, in his Neoplatonic criticism of Aristotle, thought it was better to reject[22]. In the theory of mathematical flow in geometry, it was by means of the flow of the point that the lines were built; by means of the flow of the line, the surface is built; and by means of the flow of the surface, the solid is built. Thus, we note in the Arabic world a concomitant development of the reception of Euclid's work, which would have been different from what can be apprehended from the Latin world, with the exception of Albert the Great, in the 13th century.

In conclusion, in the Latin-speaking medieval world we notice two moments, whose inflexion point would be precisely the reception of the Arabic philosophy and science from the Christian reconquest of the Iberian Peninsula in the 12th century, under Arabic domination at the time.

One knows that Boethius translated Euclid's *Elements*. Nonetheless, this work is also lost. And it is possible that it had already been lost in the 13th century. However, translations attributed to him circulated. Migne's *Latin Patrology* (v. 64) attributes two translations to Boethius, one of the first book and another of the second book of the *Elements*. With regard to the first book, the translation is probably from the 10th century[23]. It was, therefore, a text that expressed the mathematical practice previous to the coming of the Arabic intellectual influence in the Latin West.

The attribution to Boethius cannot be ignored because the very idea of mathematics as independent of movement dates back to Boethius' discussions on the three speculative sciences. Therefore, the idea of the need of a flow to build mathematical objects would seem completely alien to the Boethian context. As an illustration, let us see the way that Pseudo-Boethius' translation presents Euclid's famous theorem I.1[24].

Pseudo-Boethius

If we take this translation as a starting point for the analysis of the translations of the Arabic Euclid, we should observe the following. First, despite the formulation of the problem and the use of the diagram, Pseudo-Boethius does not translate the construction and the demonstration of the proof. We can assume that this would be a task for the geometry student. Nonetheless, from the point of view of the mathematical practice, Pseudo-Boethius does not need to make any reference to movement, neither in the definition – which Euclid does not use in a genetic mode –, nor in the demonstration, which is not translated to Latin.

[21] Cf. ANARITIUS; TUMMERS, 1994, p. 1.

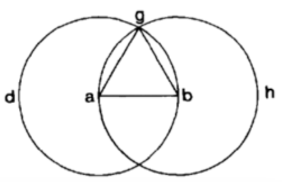
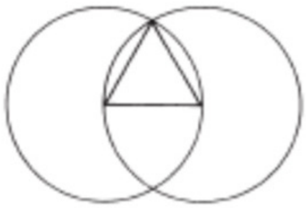
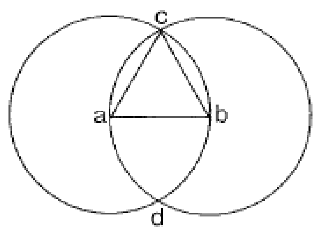
[22] For further details on Proclus rejection of the doctrine of flow in mathematics, cf. VINEL, 2010.

[23] For a detailed analysis of Migne's edition, as well as eventual fragments of Boethius' original translation, cf. BUSARD, 1998.

[24] It is worth mentioning that this translation presented in Migne's edition (PL, 64, p. 1307) attributes the *Elements* to Euclid of Megara.

On the other hand, in the 12th century, along with the reconquest of the Iberian Peninsula, an intense movement of translation of philosophical and scientific works to Latin arises. The same happens to Euclid. In this context, there are three translations of the *Elements*, by Adelard of Bath, Robert of Chester, and John of Tinemue, respectively. Previously, the three translations were attributed to Adelard, known as Adelard I, II, and III. Besides the translations of Ptolemy and Al-Kwarizimi, we stress the translation of Al-Nayrizi's *Commentary* on the *Elements*, done by Gerard of Cremona.

Let us check how the three Arabic-Latin translations present the same problem in *Elements* I.1:

ADELARD I (ADELARD OF BATH)	ADELARD II (ROBERT OF CHESTER)	ADELARD III (JOHN OF TINEMUE)
I.1 Now we must demonstrate how we will produce a triangular surface with equal sides in a straight line of determined quantity.  Let ab be the determined line. Build a circle gdb, with the center in a and occupying the space between a and b. Besides, draw the circle gah, with the center in b, occupying the space between a and b. Furthermore, start from point g, over the section of the circles, two straight lines to point a and to point b. I then say that we drew a triangle with equal sides on line ab[25].	I.1 How to place an equilateral triangle on a given straight line.  From both extremes of the given line, draw two circles that cut themselves with the compass. And from the very section common to both circles, to both extremes of the mentioned line, trace lines. Subsequently, therefore, from the description of the circle, produce the argument[26].	I.1 How to place an equilateral triangle on a given straight line.  (...) Let us draw the circle with the space ab in accordance with the second postulate. Thus, we fix the immovable foot of the compass in b, and with the movable foot in a, let us trace a second circle following the same space in accordance with the center b, touching the previous [circle] in d and in c, subsequently we have built the hypotenuses [diagram?] from ab to section c[27].

[25] ed. BUSARD, 1983, p.33-34: "I.1 Nunc demonstrandum est quomodo superficiem triangulam equalium laterum super lineam rectam assignate quantitatis faciamus.

Sit linea assignata ab. Ponaturque centrum supra a occupando spacium quod est inter a et b circulo, supra quem gdb. Item ponatur supra centrum b occupando spacium inter a et b circulo alio, supra quem gah. Exeantque de puncto g supra quem incisio circulorum due linee recte ad punctum a et ad punctum *b*. Sintque ille *ga* et *gb*. Dico quia ecce fecimus triangulum equalium laterum supra lineam *ab* assignatam."

[26] ed. BUSARD, 1992, p. 115: "I.1 Triangulum equilaterum super datam lineam rectam collocare.

A duobus terminis date linee ipsam lineam occupando cum circino duos circulos sese invicem secantes describe et ab ipsa communi seccione circulorum ad duos terminus linee proposite duas rectas lineas dirige. Deinde ergo ex circuli descripcione argumentum elice."

[27] ed. BUSARD, 2001, p. 36: "I.1 Triangulum equilaterum supra datam lineam rectam collocare. (...)

Dispositio. Supposito itaque centro in a, circumferentia vero in b, designetur circulus secundum spatium ab iuxta secundam petitionem. Item fixo pede pigro circini in b, mobili vero in a, designetur et alius circulus secundum idem spatium circa b centrum secans priorem in d et in c, ypothenusis denique erectis ab ab in c sectionem."

Nowadays, we are used to think about Euclid from Heiberg's canonical edition. However, the very transmission of Euclid, both textual and diagrammatic, does not allow a restrictive view of the text of the *Elements*.

In the case of the Arabic-Latin translations, we note the following. In the first place, the diagrammatic construction is totally divergent. Robert of Chester's translation does not even make use of indexes to mark the sections of the circles. The first translation (Adelard I) presents a diagram similar to the one edited by Heiberg, with an index only in the superior section of the circles. John of Tinemue's translation presents indexes for both sections.

With regard to the proof, John of Tinemue's translation makes reference to the "movable foot of the compass" when he introduces both the tool and the notion of movement in the mathematical proof. That is something that differs completely from the Latin medieval mathematical practice, in which Boethius ideal that mathematics is separated from movement was generally followed.

The proof translated by Robert of Chester has also a constructive tone, presenting the need of drawing the circle with the compass. Because it does not bring indexes, the proof is more syncopated, differing from John of Tinemue's translation, and only indicating that one needs to trace circles that cut themselves, so that the equilateral triangle can be built.

Lastly, Adelard I's translation does not explicitly mention the compass or movement, but it only states the need of tracing two circles (*gdb & gah*) and two straight lines from the point arising from the section of the circles to the extremes of the given straight line.

Notwithstanding, it is interesting to notice that these two different translations of Euclid interpolate in the textual transmission, as can be observed in the reception by Albert the Great. In the first half of the 13th century the new translations of Euclid are received by Albert the Great and Roger Bacon, and both of them produced commentaries on the *Elements*[28].

Albert is an author who shows a special interest in the philosophy of mathematical practice because he produced commentaries on Euclid's *Elements* and on Aristotle's *Posterior Analytics*[29]. Nonetheless, let us check Albert commentary on the same problem in Euclid's *Elements*.

[28] Roger Bacon commentary on the *Elements* was previously attributed to Adelard of Bath. Cf. BUSARD, 1974.

[29] On the discussion of the role of the demonstration through formal causality in mathematics, particularly in the 13th century, cf. SILVA, 2018.

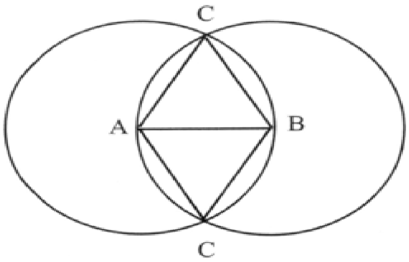
ALBERTUS MAGNUS – Euclid I. 1

I. 1 On a given straight line, build an equilateral triangle.

Let there be a straight line AB. Furthermore, in accordance with the third postulate, I place the immovable foot of the compass in A and trace a circle according to the quantity AB. Then, in accordance with the same postulate, I place the immovable foot of the compass in B and, with the quantity of the same line, I trace another circle. C is the point of intersection between the circles. Thus, in accordance with the first postulate, I connect A with C and, equally, B with C. I then say that the triangle ABC is equilateral.

(...)

This can be formulated in a syllogism in the following way: every rectilinear triangle with sides equal to the lines that start from the same center of the same circle is equilateral. Now, the triangle ABC was built on line AB that has etc.; thus, it is equilateral. Next, you see the diagram[30].



Therefore, in his commentary on Euclid, Albert is clearly influenced by the Arabic-Latin translations. We notice the following:

1) the diagrams presented by Albert bring indexes of the points, which can be accompanied by the demonstration. In this regard, he complies with Adelard I and John of Tinemue's translations[31];

2) the formulation of the problem in Albert is similar to Pseudo-Boethius' formulation:
Albert: *supra datam rectam lineam aequilaterum triangulum constituere*,
Pseudo-Boethius: *supra datam rectam lineam terminatam triangulum aequilaterum constituere*;

3) the diagram presented is similar to John of Tinemue's diagram because, besides presenting indexes, like Pseudo-Boethius and Adelard, he presents indexes for both sections of the circles, both in the superior part – as it was later established in Heiberg's edition of the Greek text – and in the inferior part;

[30] ed. TUMMERS (= ALBERTUS MAGNUS, ed. Col., XXXIX), 2014, p. 14: "I. 1 Supra datam rectam lineam aequilaterum triangulum constituere.

Sit enim data recta linea ab. Per secundam autem petitionem pono pedem circini immobilem in a et ad quantitate ab lineae circumducam circulum. Deinde per eandem posito immobili pede circini in b describam ad eiusdem lineae quantitatem alium circulum, sitque punctum c locus sectionis circulorum. Deinde per primam petitionem continuabo a cum c et similiter b cum c. Dico igitur quod abc est triangulus aequilaterus. (...)

Syllogizetur ergo sic: omnis triangulus rectilineus latera habens aequalia lineis egrendientibus ab eodem centro ad eandem circumferentiam est aequilaterus. Sed triangulus abc super datam lineam ab constitutus est habens etc., ergo est aequilaterus. Schema autem est ut vides."

[31] The diagrams of the Heiberg's standard Greek edition belong to the editor, not to a critical edition of the manuscripts. For an edition proposal of Euclid's diagrams, cf. SAITO, 2006.

4) distancing himself from the medieval Latin practice, Albert makes reference to the "movable foot of the compass"[32] during the demonstrations, like John of Tinemue. Although it was uncommon in the medieval period, the reference to a movable foot of the compass opposed the Boethian common understanding that mathematics is independent from movement;

5) the formulation of a syllogism as metatheorem, in which the demonstration of the proof I.1 would work as major premise. It is worth mentioning that, throughout the *Commentary* on Euclid's first four books[33], other syllogistic reconstructions are not frequent. One may conjecture that, in this context, Albert presents the syllogistic reconstruction of *Elements* I.1 as an example that could be followed throughout the commentary.

Conclusion

Albert the Great is a unique author with regard to his discussion on the nature of geometry. His encyclopedic spirit and tendency to conciliate diverse theories led him to accommodate the different versions of Euclid that circulated at the time. Besides the reception of the commentary on the *Elements* by the mathematician Al-Nayrizi, John of Tinemue's (Adelard III) translation led him to incorporate the reference to the compass and movement in the geometrical demonstration. The pre-Arabic view in the Latin world excluded any role to movement in mathematics. Albert, in turn, besides the philosopher's perspective, presents the mathematician's view, who needs a ruler and a compass, moving them in order to practice his own science.

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[32] I thank Marco Panza, who drew my attention to this aspect of Albert's text, common in modern times, but uncommon in the medieval period.

[33] These are the books known, contained in the manuscript Wienerkloster 80/45, edited by Tummers. Albert would have commented the first ten books of Euclid's *Elements*, following what Al-Nayrizi had done; nonetheless, the rest of the work remains unknown.

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