Qusṭa ibn Lūqā and Alfonso X on the celestial globe

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1. Celestial Spheres in the medieval Iberian Peninsula[1]

The celestial globe seems to have been known in al-Andalus and in the Christian kingdoms of the Iberian Peninsula in the tenth century, although evidence of it is scarce. Both the *Almagest* and al-Battānī's *al-Zīj al-Ṣābi'*, which contained respectively the description of a precession globe[2] and of the *bayḍa*, a sophisticated instrument of the same kind, were available to Maslama al-Majrīṭī (d. 1007)[3]. Probably also in the second half of the

[1] This paper contains a thorough revision and updating of J. Samsó, "El tratado alfonsí sobre la esfera", *Dynamis* (Granada) 2 (1982), 57-73. It has been prepared within a research programme on "Science and Society in the Western Mediterranean during the later Middle Ages" sponsored by the Spanish Ministerio de Educación y Ciencia and by FEDER (project number HUM2004-02511.

[2] *Almagest* VIII, 3. See G.J. Toomer, *Ptolemy's Almagest* (New York, Berlin, Heidelberg, Tokyo, 1984), pp. 404-407; O. Neugebauer, *A History of Ancient Mathematical Astronomy* (Berlin, Heidelberg, New York, 1975) II, 890-892; E. Savage-Smith, *Islamicate Celestial Globes: Their History, Construction and Use* (Washington, 1985), pp. 8-11.

[3] C.A. Nallino, *Al-Battānī sive Albatenii Opus Astronomicum* vol. I (Milan, 1903), pp. 139-142 and 320-321; Savage-Smith, *Islamicate Celestial Globes* pp. 18-20.

tenth century a short Latin tract appears, entitled *Incipit de horologio secundum alkoram, id est speram rotundam*, which belongs to the early Arabic-Latin texts of the "old corpus" or "old collection", and deals with the use of the solid sphere[4]. In the eleventh century the great Toledan astronomer Abū Isḥāq Ibrāhīm ibn Yaḥyā al-Naqqāsh, known as Ibn al-Zarqālluh/ Ibn al-Zarqiyāl/ Azarquiel (d. 1100), who was also an instrument maker, criticizes the defects of spheres made in his time by other artisans and mentions that he himself built a celestial globe which could be adapted to any latitude with the precision of one degree[5]. His contemporary, Ibrāhīm ibn Saʿīd al-Sahlī (fl. 1080), also built celestial globes, of which two are extant in Florence and Paris[6]. In the thirteenth century, in addition to the Alfonsine treatise on the celestial globe - which is the main topic of the present paper - an instrument of this kind, extant in the library of the hospital founded by Nicholas Cusanus in Berncastel-Kues, has also been considered to have an Alfonsine origin,[7] although this ttribution does not seem to be well established.[8]About a century later,

[4] Edition by J.M. Millàs Vallicrosa, *Assaig d'història de les idees físiques i matemàtiques a la Catalunya Medieval* (Barcelona, 1931), 288-290. Millàs believed that the instrument in question was a spherical astrolabe, something which is not impossible. R. Lorch, however, argues that it is a celestial globe: see his paper "The *sphaera solida* and related instruments" in *Centaurus* 24 (1980), 153-161 (reprint in Lorch, *Arabic Mathematical Sciences*. Variorum. Aldershot, 1995, no. XII). I believe that the instrument described is related to al-Battānī's *bayḍa*: see J. Samsó, "Els inicis de la introducció de la ciència àrab a Europa a través de Catalunya", in Joan Vernet i Ramon Parés (dirs.), *La ciència en la història dels Països Catalans. I. Dels àrabs al Renaixement*. Institut d'Estudis Catalans - Universitat de València. València, 2004, pp. 115-159.

[5] J. Samsó, *Las Ciencias de los Antiguos en al-Andalus* (Madrid, 1992), pp. 173-175.

[6] M. Destombes, "Globes celestes et catalogues d'étoiles orientaux du Moyen Age", in *Actes du VIII^e Congrès International d'Histoire des Sciences* (Florence, 1966), 313-324; reprint in Destombes, *Contributions sélectionnées à l'Histoire de la Cartographie et des Instruments Scientifiques* (Utrecht - Paris, 1987), 79-89. Savage-Smith, *Islamicate Celestial Globes* pp. 24, 217, 236.

[7] A. Domínguez, "La representación de la esfera en el círculo de Alfonso el Sabio. Mapas del cielo inéditos en la Academia de la Historia y el globo de Nicolás de Cusa". *Boletín del Seminario de Estudios de Arte y Arqueología* (Valladolid) 50 (1984), 408-410.

[8] M. Comes, "Sobre la procedencia alfonsí de un globo celeste" in M. Comes, R. Puig and J. Samsó, *De Astronomia Alphonsi Regis. Proceedings of the Symposium on Alfonsine Astronomy held at Berkeley (August 1985) together with other papers on the same subject*

in December 1361, Pere Gilbert and Dalmau ses Planes, astronomers of Peter IV of Aragon (1336-1387), finished the construction of a great sphere in Barcelona, with a diameter of seven spans, which they used to display the positions of fixed stars according to the observations they made between 1360 and 1366.[9]

The Alfonsine book on the solid sphere is, as we will see presently, a good introduction to elementary spherical astronomy. This is why I would like to complement the previous list of references to celestial globes in the medieval Iberian Peninsula with others concerning astronomical or geometrical treatises which dealt with the sphere. It is well known that Classical books on the sphere written by Autolycos of Pitane (fl. ca. 300 B.C.)[10] Menelaos (fl. 98 A.D.), and Theodosius of Tripoli (first century A.D.)[11], circulated in Latin in translations made by or ascribed to Gerard of Cremona, that there also was a Latin translation of the short elementary treatise entitled *De recta imaginatione spere et circulorum eius*, ascribed to Thābit b. Qurra[12], and, finally, that the inventory, made in 1410, of the library of the Royal Palace in Barcelona mentions a Latin book with the title of *Spera solide*[13]. I can add to this two quotations of Theodosius and Autolycos extant in Spanish vernacular texts between the thirteenth and the beginning of the fifteenth century. Proposition I, 16 of Theodosius' book is quoted by the Alfonsine astronomers both in the

(Barcelona, 1987), 139-152.

[9] J.M. Millás-Vallicrosa, *Las Tablas Astronómicas del rey D. Pedro el Ceremonioso* (Madrid-Barcelona, 1962), 66-68 and 124.

[10] See J. Mogenet, "La traduction latine par Gérard de Crémone du Traité de la Sphère en Mouvement d'Autolycus", *Archives Internationales d'Histoire des Sciences* 5 (1948), 139-164.

[11] See Paul Ver Eecke, *Les Sphériques de Théodose de Tripoli*. Paris, 1959; J.M. Millás Vallicrosa, *Las traducciones orientales en los manuscritos de la Biblioteca Catedral de Toledo* (Madrid, 1942), p. 208.

[12] F.J. Carmody, *The Astronomical Works of Thabit b. Qurra*. Berkeley and Los Angeles, 1960, pp. 118-119 and 140-144.

[13] J. Chabás with the collaboration of A. Roca and X. Rodríguez, *L'astronomia de Jacob ben David Bonjorn* (Barcelona, 1992), p. 29.

treatises on the sphere[14] and on the spherical astrolabe[15]; and the first proposition of Autolycos' *De sphaera mota* appears quoted (as *D'espera mobili* or *Tractado de la esphera movible* by Talocus/ Thalocus) by the Spanish writer Enrique de Villena (1384-1434) in his *Glosas a la Eneida*[16].

2. The Alfonsine treatise "Libro de la fayçon dell espera"

2.1 *Introduction*

This book is the second of the *Libros del Saber de Astronomía* in the order in which they appear in the royal codex of the collection (Villamil 156, Universidad Complutense de Madrid)[17]. A short prologue, totally independent of any Arabic source, states that it deals with the instrument called *alcora* (Ar. *al-kura*, i.e. sphere) or *vet* [*sic* instead of *det*] *alcorcy* (Ar. *dhāt al-kursī*, i.e. the globe, with a chair or stand) and establishes a dependence with the book written by the Oriental scholar *Cozta*: the source mentioned is obviously the *Risāla fī l-kura al-falakiyya*, *Kitāb al-ᶜamal bi l-kura al-falakiyya/ al-nujūmiyya*, *Risāla fī l-ᶜamal bi l-kura [dhāt al-kursī]* - as it appears in the different manuscripts - written by the well known scientist and translator Qusṭā b. Lūqā (fl. second half of the ninth century)[18]. The prologue explains clearly, however, that the book is

[14] I will quote the Alfonsine texts in the edition of M. Rico y Sinobas, *Libros del Saber de Astronomía*. 5 vols. Madrid, 1863-1867. See I, 206.

[15] Rico II, 127.

[16] I know this reference through the unpublished doctoral dissertation by Pedro M. Cátedra (*Sobre la vida y la obra de Enrique de Villena*. Universidad Autónoma de Barcelona, september 1981).

[17] Ed. Rico I, 153-209. An excellent facsimile edition of codex Villamil 156 has been published in Barcelona, 1999 (two volumes).

[18] F. Sezgin, *Geschichte der Arabischen Schrifttums. Band VI: Astronomie bis ca. 430 H.* Leiden, 1978, pp. 180-181. See, on this treatise, W.H. Worrell, "Qusta ibn Luqa on the Use of the Celestial Globe", *Isis* 35 (1944). I have not been able to see H. Schnell, *Die Kugel mit dem Schemel*, Inaug. Diss., Erlangen, 1924, which contains a complete German translation of Qusṭā's book. For the comparison between the Arabic and the Castilian texts I have used here mss. Teheran, A. Mahdawī 503 and Istanbul, Ahmet III 3505: photocopies of these two mss. were sent to me by Richard Lorch to whom I would

divided into three parts:

1. Four initial chapters, which deal with the construction of the instrument, a topic which does not appear in Qusṭā b. Lūqā's book. No author is mentioned for this part of the Alfonsine work, but it has been reasonably ascribed to Isḥāq b. Sīd, who often appears as the author to whom the king asks to write an original treatise on the construction of astronomical instruments, when an adequate Arabic source cannot be found.[19]

2. The sixty-five chapters of the Castilian translation of Qusṭā b. Lūqā's book on the *use* of the instrument. The translators were Yehūdah b. Mosheh ha-Kohen[20] and the cleric Johan Daspa, who finished their work on the 6th of February 1297 of the Spanish Era (1259 A.D.). The translation was revised in 1315 S.E./1277 A.D., and it is this revised translation that appears in the royal codex.

3. An additional chapter appears after the completion of Qusṭā b. Lūqā's treatise. Following the King's orders, a certain Don Mosheh[21] describes an auxiliary quadrant and an armillary semicircle which he uses, in combination with the globe, to divide the houses of the horoscope and to calculate the *ataçir* (i.e. *al-tasyīr*).

like to express my gratitude.

[19] See D. Romano, "Le opere scientifiche di Alfonso X e l'intervento degli ebrei", in *Oriente e Occidente nel Medioevo: Filosofia e Scienze*. Accademia Nazionale dei Lincei (Roma, 1971), 677-711 (see pp. 689-690, 693, 705) [reprint in Romano, *De Historia Judía Hispánica*. Barcelona, 1991, pp. 147-181]. On the scientific collaborators of Alfonso X, see also E.S. Procter, "The Scientific Works of the Court of Alfonso X of Castile: the King and his Collaborators", *Modern Language Review* 40 (1945), 12-29; N. Roth, "Jewish Translators at the Court of Alfonso X", *Thought* 60 (1985), 439-455; Roth, "Jewish Collaborators in Alfonso's Scientific Work" in Robert I. Burns (ed.), *Emperor of Culture. Alfonso X the Learned of Castile and His Thirteenth Century Renaissance* (Philadelphia, 1990), 59-71, 223-230.

[20] On this author see G. Hilty, "El Libro Conplido en los Iudizios de las Estrellas", *Al-Andalus* 20 (1955), 1-74.

[21] The spelling *Don Xosse* which appears in Rico's edition (I, 206) is an obvious misprint. See the edition by L. Kasten and J. Nitti, *Concordances and Texts of the Royal Scriptorium Manuscripts of Alfonso X, el Sabio*. Madison, 1978.

2.2 *Description of the instrument*

The description of the instrument appears both in the first four chapters, on the construction of the celestial globe, and in the fifth chapter of the Alfonsine text (the first chapter of Qusṭā b. Lūqā's treatise)[22] which is the standard opening of a work on the use of an astronomical instrument. The Alfonsine treatise offers, obviously, many details on the construction of the instrument which are not mentioned in the Arabic original[23] and even the general design of the celestial globe presents substantial differences between the two treatises which I will try to outline in the following pages. This offers me the first opportunity to state that, even if the *Alcora* can be considered, in general terms, a faithful translation of the Arabic original[24], Yehudah b. Mosheh and Johan Daspa do not hesitate to expand or modify when they deem it necessary.

Both texts (chapter 1/5) describe a celestial globe on which appears the circle of the ecliptic and that of the equator, as well as their poles and the great circles of longitude which correspond to the beginnings of the zodiacal signs[25]. Both the ecliptic and the equator are divided into 360°, although the ecliptic appears divided into twelve sections of 30° each, which correspond to the zodiacal signs, while the division into degrees of the equator is consecutive from 1° to 360°. While the Alfonsine chapter 3 uses an obliquity of the ecliptic of 24°,[26] chapter 1/5 does not mention a value for this parameter, but 23;33° appears in chapter 30/34 on the use

[22] The Alfonsine treatise (69 chapters) follows carefully the chapter division of the Arabic text (65 chapters), but as it adds four extra chapters at the beginning, there is a constant difference of 4 between the chapter numbers of the two versions. My references will be to the corresponding chapter number in such a way that *chapter 1/5* means first chapter of the Arabic original/ fifth chapter of the Alfonsine translation. See Rico I, 154.

[23] Concerning the materials used and the construction techniques see Savage-Smith, *Islamicate Celestial Globes* pp. 81-82.

[24] A classification of the Alfonsine astronomical translations and original works can be found in J. Samsó, "Las ciencias exactas y físico-naturales" in J.A. García de Cortázar (ed.), *La época del gótico en la cultura española (c. 1220- c. 1480* (*Historia de España Menéndez Pidal*, vol. XVI, Madrid, 1994), pp. 553-593 (see especially pp. 558-566).

[25] Both texts mention twelve circles: they are, in fact, six.

[26] Rico I, 166.

of the instrument[27], and 24° is implicit in several others (47/51, 49/53, 50/54, 51/55, 52/56). An important difference between the two texts (chapter 1/5) appears in relation to the stars projected on the surface of the globe itself: the Arabic treatise mentions the twenty eight lunar mansions (*manāzil al-qamar*), represented by circles of different size, to which Qusṭā b. Lūqā adds a small number of brilliant stars (small circles having the same diameter) which he identifies as those usually projected on the astrolabe. The Alfonsine translators seem to have considered the lunar mansions inadequate for a cultural world which did not use a lunar calendar, eliminating all references to them in their translation of this chapter: in fact the Castilian text replaces them by the forty eight constellations of Ptolemy's star catalogue (not mentioned in Qusṭā's treatise) and by an undetermined number of stars within each constellation (represented by circles of different size according to the magnitude of the star). There is, then, an entirely different approach in the two texts in relation to the stars which appear on the globe. Although the Castilian text does not state it explicitly, the implication is that the Alfonsine globe probably aimed to depict the full set of stars listed in star catalogues (class A in Savage-Smith's classification of Islamicate celestial globes), while the globe described by Qusṭā b. Lūqā corresponds to class B (in the same classification), in which there are no constellation outlines, the number of stars is limited, and astrolabe stars are nearly always included.[28]

Qusṭā b. Lūqā mentions two other circles: the horizon and the meridian. The former is a ring (*ḥalqa*) placed on the upper surface of the stand (*kursī*, *siella* or "chair"), divided into 360°. There is no description of the stand in chapter 1/5, but we find it in chapter 4 of the Alfonsine text, which is entirely independent of Qusṭā's treatise[29]. It has the shape of a square box with a graduated circular ring in its upper surface (horizon) and rectangular openings in its four sides: the user can introduce his hand through these openings in order to move the sphere. The meridian is a ring, also divided into 360°, which is fixed on the two

[27] It is the value established in 213 H./828-29 by Yaḥyā ibn Abī Manṣūr in Baghdad. See Jamil Ali, *The Determination of the Coordinates of Positions for the Correction of Distances between Cities. A Translation from the Arabic of al-Bīrūnī's Kitāb Taḥdīd Nihāyāt al-Amākin Litaṣḥīḥ Masāfāt al-Masākin*. Beirut, 1967, p. 60.

[28] For this classification see Savage-Smith, *Islamicate Celestial Globes* p. 61.

[29] Rico I, 168-169.

equatorial poles of the sphere by means of two nails (*mismār*, *priego*) which allow the sphere to rotate inside the meridian ring (chapter 1/5). The meridian ring - which holds the sphere - stands on a pivot placed in the centre of the lower surface of the *kursī*/ *siella* and is fixed on it by two guides in the northern and southern points of the horizon: in this way the meridian ring can slide so that the pole forms with the horizon an angle equal to the local latitude[30].

Qusṭā b. Lūqā's instrument corresponds, therefore, to the simplest kind, also described by Ḥabash al-Ḥāsib[31] equipped with only two rings (meridian and horizon). The same can, obviously, be said of the Alfonsine text between chapters 5 and 69. As for the first four Alfonsine chapters on the construction of the instrument, they introduce a third graduated ring, called the smaller armilla (*armilla menor*) to distinguish it from the meridian ring (*armilla mayor*). The smaller ring is fixed to the two poles of the ecliptic and can rotate freely around them and underneath the meridian ring, being able to represent any great circle of celestial longitude. The purpose of the ring is obvious: it can be used to determine the position of any celestial body in longitude and latitude as is explicitly stated in chapter 3 of the Castilian text. A ring of this kind appears in Ptolemy's description of his precessional globe, but I do not know of any Islamic text or instrument which mentions or includes one. It is possible that the Alfonsine collaborator who wrote the four chapters on the construction of the instrument used the *Almagest* as his source of inspiration for the *armilla menor*: the *Almagest* is quoted in relation to the construction of the celestial globe in the Alfonsine treatise on the spherical astrolabe[32] and MS Escorial 915, which contains Isḥāq b. Ḥunayn's translation of Ptolemy's work, seems to have been copied at the Alfonsine court[33].

[30] See chapter 1/5. Further details on the mounting of the instrument in chapter 4 of the Alfonsine treatise (Rico I, 168-169).

[31] Richard Lorch and Paul Kunitzsch, "Ḥabash al-Ḥāsib's Book on the Sphere and its Use", *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften* 2 (1985), 68-98 (reprint in Lorch, *Arabic Mathematical Sciences* no. XIII).

[32] Rico II, 121.

[33] Samsó, "Alfonso X and Arabic Astronomy" in *De Astronomia Alphonsi Regis*, p. 27 (reprint in Samsó, *Islamic Astronomy and Medieval Spain*. Variorum, Aldershot, 1994, no. XIII).

2.2.1 *The auxiliary quadrant*

It is interesting to examine the procedure described by Qusṭā b. Lūqā, and followed by the Alfonsine translation, to determine the position of a celestial body in longitude and latitude with a globe that does not have this smaller ring[34]. In 53/57 Qusṭā b. Lūqā describes an auxiliary graduated quadrant to determine the solar altitude by fixing one of its ends on the zenith and the other on the horizon. The same quadrant is also used in 58/62 to determine the longitude of the Moon or of any planet: now one of the ends of the quadrant is fixed on the pole of the ecliptic and the other one on the ecliptic itself. This auxiliary quadrant appears described in other globe texts such as those written by al-Ṣūfī (903-986)[35], al-Khāzinī (fl. 1115-1130)[36], Abū 'l-Ḥasan ᶜAlī al-Marrākushī (13th c.)[37] and in a Latin treatise on the solid sphere ascribed to Johannes of Halebeke or Harlebeke (fl. Paris 1303)[38]. It is rather curious that Qusṭā does not mention this useful auxiliary quadrant until chapter 53 of the Arabic text, and uses approximate methods instead. Thus, in chapter 20/24 Qusṭā describes how to determine the longitude of a star and he is forced to use the meridian ring: the degree of the ecliptic that crosses the meridian together with the star (i.e. the mediation of the star) is

[34] Abū 'l-Ḥasan ᶜAlī al-Marrākushī easily solves the problem because his "meridian" armilla can be pivoted on the poles of the equator or on the poles of the ecliptic. See al-Marrākushī, *Jāmiᶜ al-mabadi' wa 'l-ghāyāt* (facsimile of ms. Istanbul Ahmet III 3343 published by the Institut für Geschichte der Arabisch-Islamischen Wissenschaften, Frankfurt, 1984) II, 7-8.

[35] E.S. Kennedy, "al-Ṣūfī on the Celestial Globe", *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften* 5 (1989), 48-93.

[36] R. Lorch, "al-Khāzinī's Sphere that Rotates by Itself", *Journal for the History of Arabic Science* 4 (1980), 287-329 (reprint in Lorch, *Arabic Mathematical Sciences* no. XI).

[37] See for example L.A. Sédillot, *Mémoire sur les instruments astronomiques des Arabes* (Paris, 1844; reprint Frankfurt, 1989) p. 115; al-Marrākushī, *Jāmiᶜ al-mabadi' wa 'l-ghāyāt* II, 5.

[38] R. Lorch, "The *sphaera solida* and Related Instruments" *Centaurus* 24 (1980), 153-161 (repr. in *Arabic Mathematical Sciences* no. XII).

considered to be equal to the longitude of the star[39]. This equivalence is only approximate and the Castilian text adds a brief description of the auxiliary quadrant which is used to establish exactly the longitude of the star. The following chapter (21/25) describes how to determine the latitude of the star and, again, the Arabic text of Qusṭā uses only the meridian ring, while the Alfonsine translation adds the exact method based on the use of the quadrant, showing clearly that the translator was well aware of the approximate character of the method used by the Arabic original[40]. In chapters 62/66 (on the determination of the longitude of a star which is not projected on the sphere if we know its meridian altitude and the meridian altitude of one of the stars which appear on the sphere) and 63/67 (on the determination of the latitude of a star not projected on the sphere if we know its meridian altitude and its longitude), we no longer have Alfonsine additions but rather entirely different texts in the Spanish translation: once more, Qusṭā b. Lūqā uses only the meridian ring while, here, the Alfonsine text - no longer a translation - describes methods based on the use of the auxiliary quadrant. These additions and corrections do not appear, however, in all the pertinent cases in which the auxiliary quadrant should have been used. In chapter 40/44, for instance, both texts use the meridian ring to determine the longitude and latitude of the Moon or of a planet, and the same happens in chapter 59/63 which aims to establish the latitude of the Moon or of a planet if we know its longitude and meridian altitude.

2.2.2 *The Alfonsine appendix*

[39] In chapter 29/33 both the Arabic text and the Castilian translation explicitly state this equivalence:

وانظر الجزء الذي توسّط معه السماء من دائرة فلك البروج فذلك الجزء جزء توسّط السماء وهو جزءه الحقّي من فلك البروج

("Look at the degree of the ecliptic which crosses the meridian together with it [= star]. That degree is the degree of its mediation and it is [also] its true degree of the ecliptic"). The Castilian text says equally: "Et aquel grado con que se para en el mediol cielo en esta oriella de esta armella, aquel es su logar de la estrella" (Rico I, 186). The same identification appears in chapter 29/33.

[40] "Et esta obra del quarto del cerco, quier por saber el logar de la estrella, quier por saber su ladeza, es mas certera, et mas drecha que la otra obra que dixiemos que se faze por la armella de mediodia" (Rico I, 181) ("And this use of the quadrant, in order to determine the place [= longitude] of the star or its latitude, is more adequate and precise than the other aforementioned method which uses the meridian ring").

When Don Mosheh wrote the appendix on the procedure for the use of the celestial globe[41] in order to calculate the *tasyīr* and to divide the houses according to the method of Hermes, he described, once more, how to make an auxiliary quadrant, divided into ninety equal parts and provided with a nail (*clauo*) in order to fix the quadrant to either of the holes made in the sphere in the northern and southern poles of the ecliptic: the text also carefully explains how to use the quadrant in order to establish on the globe the position in longitude and latitude of a celestial body. It is interesting to remark, here, that Don Mosheh seems to have written his appendix without reading either the Alfonsine translation of Qusṭā b. Lūqā's treatise - where, as we have seen, the auxiliary quadrant is described and used - or the first four chapters of the book on the construction of the instrument: the auxiliary quadrant is not needed for the determination of ecliptic coordinates if we have the *armilla menor*, fixed to the poles of the ecliptic. This is not the only instance of Alfonsine collaborators working independently of each other and being unaware of the work of their colleagues[42].

Don Mosheh also adds to the instrument half an armilla (*media armella dell ataçyr)*, provided with a movable index (*demostrador*), the ends of which will be fixed to the northern and southern points of the horizon. This semiarmilla is used to calculate the *tasyīr*[43] and can also be used to divide the houses according to the method of Hermes, the "prime vertical method", in North's terminology[44]. This is the second

[41] Rico I, 206-209.

[42] See J. Samsó and F. Castelló, "An Hypothesis on the epoch of Ptolemy's star catalogue according to the authors of the Alfonsine Tables".- *Journal for the History of Astronomy* 19 (1988), 115-120. Reprint in Samsó, *Islamic Astronomy and Medieval Spain*, Variorum, Aldershot, 1994, no. XX.

[43] M. Viladrich and R. Martí, "Sobre el *Libro dell ataçir* de los *Libros del Saber de Astronomía* de Alfonso X el Sabio", J. Vernet (ed.), *Nuevos Estudios sobre Astronomía Española en el siglo de Alfonso X* (Barcelona, 1983), 75-100 (see especially pp. 88-90).

[44] J. North, *Horoscopes and History*, London, 1986, pp. 36-38. This method is also described in three other Alfonsine books: *Libro del Astrolabio Redondo*, *Libros de la Lámina Universal* and *Libro de la açafeha*. On the prime vertical method and its introduction in al-Andalus see also E.S. Kennedy, "Ibn Muᶜādh on the Astrological Houses", *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften* 9 (1994), 153-160; Kennedy, "The Astrological Houses as Defined by Medieval Islamic Astronomers", J. Casulleras and J. Samsó (eds.), *From Baghdad to Barcelona. Studies*

method for the division of the houses of the horoscope which appears in the Alfonsine text, for chapter 55/59 explains how to use the globe in order to divide the houses according to the so-called *standard* method. For the prime vertical method, don Mosheh needs a second semiarmilla which will be attached to the East and West points of the horizon and which will pass by the zenith, thus representing the prime vertical. This semiarmilla will be divided into six equal parts (i.e. six arcs of thirty degrees each)[45] and, obviously, if the *tasyīr* semiarmilla is pivoted on the North and South points of the horizon and is free to move in the North-South direction, its intersection with the thirty degree divisions of the "prime vertical" semiarmilla will determine, on the ecliptic, the beginnings of the houses according to this method[46]. The Alfonsine text is, however, somewhat confusing; when it describes the prime vertical semiarmilla for the first time, it states that its use is to fix the *tasyīr* semiarmilla so that it will not move when the sphere rotates.

2.3 *The Alfonsine translation of Qusṭā b. Lūqā's treatise*

I have classified elsewhere[47] the Alfonsine scientific works into faithful translations (*Açafeha*[48], *Canones de Albateni*), interpolated translations (*Picatrix*, *Lapidario*, *Libro de las Cruzes*, Ibn al-Haytham's *Cosmology*), translations with original additions (*Lamina universal*,

in the Islamic Exact Sciences in Honour of Prof. Juan Vernet (Barcelona, 1996), II, 535-578; J. Samsó, "'al-Bīrūnī' in al-Andalus", *From Baghdad to Barcelona* II, 583-612.

[45] Viladrich and Martí (*Libro del Araçir* p. 98 n. 31) remark that there is a mistake in Rico's edition (I, 208). In the edition of Kasten and Nitti, the text states clearly that the semiarmilla is divided into six parts, hypothetically equal.

[46] "pornemos ell armella del ataçyr sobre cada parte destas partes, et moueremos el demostrador fasta que se encuentre con el zodiaco, et mostrarnos a las casas segund la opinion de Hermes" (Rico I, 208).

[47] J. Samsó, "Las ciencias exactas y físico-naturales" in *La época del gótico en la cultura española (c. 1220- c. 1480*, pp. 558-566.

[48] Millás noted the literalism of Alfonsine translations but his analysis was based only on Ibn al-Zarqālluh's *Açafeha*: see J.M. Millás Vallicrosa, "El literalismo de los traductores de la corte de Alfonso el Sabio", *Al-Andalus* 1 (1933), 155-187. R. Puig, *Los Tratados de Construcción y Uso de la Azafea de Azarquiel*, Madrid, 1987, has proved that this treatise is, actually, a very literal translation.

Alcora), adaptations (*Astrolabio redondo*) and false translations (*Ochaua Espera*). In the case of the *Alcora*, even if it can be considered, in general terms, a faithful translation of the Arabic original, Yehudah b. Mosheh and Johan Daspa do not hesitate to expand or modify when they deem it necessary. I have already mentioned changes introduced by the Alfonsine translators in relation to the stars projected on the sphere or on the use of the auxiliary quadrant. Other examples can easily be quoted. They are, sometimes, unimportant amplifications, or changes in the order of exposition[49], of the Arabic text, attempting to explain it in a more complete way. This is the case of a passage (chapter 4/8) in which Qusṭā deals with the people who live south of the equator, of whom he states:

وإنّهم شبيه بالبهائم لا بناء لهم ولا صناعة ولا علم

("They are like beasts and have no buildings, techniques or science").

The Castilian translation is slightly modified and insists on the idea of law as an important element in human civilisation, a not unexpected emphasis in the court of Alfonso X, who was a legislator of note:

> *Et son gentes semblantes de bestias, que non an ley, nin reglas, nin drechos, nin saber nin maestrias*[50] ("They are like beasts and have no laws, rules, rights, knowledge and crafts")

In other instances the Castilian translation explains concepts which are not common knowledge outside the Islamic community. This is the case of chapter 57/61, which explains an approximate, and obviously incomplete[51], method to determine the *qibla*: the Spanish version translates the Arabic text faithfully but adds "la linna dell alquibla, que

[49] See the amplifications in chapters 6/10, 7/11, 18/22, 28/32; changes of order in 13/17, 28/32. In chapters 32/36 and 33/37 which deal, respectively, with the use of the sphere to obtain the rising times in right and oblique ascensions of the zodiacal signs, the Alfonsine translation tends to give examples for specific cases (signs of Aries, Taurus, Gemini), while Qusṭā often limits himself to a general reference to a zodiacal sign.

[50] Rico I, 172.

[51] Both the Arabic and the Castilian texts determine the *qibla* as a function of the difference of longitudes between the place in question and Mecca and forget about the latitudes of the two cities.

quier dezir la parte haza que los moros fazen oracion"[52] ("The *qibla* line, which means the direction towards which the Moors say their prayers"). This reference seems to be quite exceptional, for in the rest of the Alfonsine astronomical works there is no mention of the *qibla*, and the problem is dealt with in a general way: how to find the direction of a given place from your location[53]. Only the book on the use of the plane astrolabe states, at the end of the corresponding chapter, that the direction of Mecca from Cordova is at 45° between East and South[54].

The *qibla* is not the only instance in which the Alfonsine translation gives an explanation of an Arabic technical term. Another interesting case is chapter 52/56, in which Qusṭā explains that in places with latitudes less than 24°, the Sun transits the local zenith twice during the year. This happens when the Sun is in a given degree of longitude [such that its declination equals the local latitude] and "in its *naẓir* in declination" (*fī naẓīri-hi fī 'l-mayl*). This Arabic expression may easily create a misunderstanding, for the term *naẓīr* of the degree (of longitude) of the Sun usually means a point in the ecliptic placed at a distance of 180°. The Castilian translation interpolates a clear explanation:

> "la una quando fuer en algun grado sennalado, et la otra quando fuer en el grado que es su opposito, *et quier dezir, el que es arredrado de la cabeça de Cancro tanto quanto ell otro*"[55] ("the first time when [the Sun] is in a determined degree, and the second when it is in the degree which is its opposite, *which means, the degree whose distance from Cancer equals the distance* [also from Cancer] *of the first degree*").

[52] Rico I, 202.

[53] See *Armellas* chapters 37-38 (Rico II, 53-54); *Astrolabio redondo* chapters 81-83 (Rico II, 202-203); *Lámina Universal* chapters 53-55 (Rico III, 116-117); *Açafeha* chapter 39 (Rico III, 192). This latter example (*Açafeha*) is less significant than the others, because Ibn al-Zarqālluh's original Arabic text also deals with the problem in a general way and does not mention the *qibla*: cf. R. Puig, *Tratados de Construcción*, pp. 72-73. See also M. Viladrich, "Una nueva evidencia de materiales árabes en la astronomía alfonsí", M. Comes, R. Puig and J. Samsó (eds.), *De Astronomia Alphonsi Regis* (Barcelona, 1987), 105-116 (especially p. 113): the author presents evidence of other instances of "censorship" in the *Astrolabio redondo* in matters related to *mīqāt* (astronomy specialised in the Islamic cult).

[54] *Astrolabio llano* chapter 57 (Rico II, 288-289).

[55] Rico I, 199.

Two degrees equidistant from a solsticial point must have the same declination. Clarification of an Arabic passage which seems excessively sparse may be useful for readers who are not always expert astronomers, and makes sense in a treatise on the celestial globe which - as we have seen - may be considered an introduction to spherical astronomy. Thus, chapter 51/55 deals with the northern or southern direction of the shadow in places with latitudes greater or smaller than 24°. The Alfonsine translation clarifies the question by stating that Qusṭā refers to the noon shadow:

> "Et esto que dezimos, siempre es en mediodia. Ca las sombras que se fazen escuentra oriente et escuentra occidente, que se fazen por el mouimiento del sol cada dia, non hy fablamos, ca manifiesta cosa es por si"[56] ("We mean at noon, for it is obvious in itself that the shadows move towards the East or towards the West as a result of the daily motion of the Sun").

In another instance, the Castilian translation omits a passage instead of giving an explanation of a technical term. This happens in chapter 41/45 which deals with the determination of the setting time of the Moon or of one of the planets. For that purpose the longitude and latitude of the Moon or planet has to be established and Qusṭā b. Lūqā recommends the use of a *taqwīm* or a *zīj*, while the Alfonsine text just skips the problem and refers to the previous chapter (40/44, on the determination of the rising time of the Moon or a planet) which merely states that one should establish the ecliptical coordinates of the celestial body involved. The omission of the *taqwīm* (ephemerides calculated for one year) is reasonable, for this kind of astronomical document was not very common in the Western Islamic tradition which cultivated the perpetual almanacs instead, but one may wonder why the Alfonsine translators did not recommend the use of a set of astronomical tables (= *zīj*). Finally, in the translation of an Arabic text which - like other similar ones[57] - is characterised by a systematic repetition of operations which are common to many chapters[58], it is interesting that in a few cases, such as the

[56] Rico I, 198.

[57] Kennedy, "Al-Ṣūfī on the Celestial Globe" p. 52.

[58] Such as, for example, moving the sphere with the meridian ring so that the North Pole forms with the horizon an angle equal to the local latitude.

aforementioned chapter 40/44, the translators avoid repetitions by referring to the other chapter which deals with a similar problem. A typical example can be found in chapters 13/17 and 14/18 which deal with the determination of the time of the day, expressed in equal (13/17) or unequal (14/18) hours, if one knows the ascendant: in both cases the process is the same and involves obtaining the hour angle. Qusṭā b. Lūqā repeats the whole set of operations in both chapters, while the Alfonsine text refers in 14/18 to what has already been explained in 13/17.

3. **Conclusions**

The Alfonsine book on the *Alcora* follows the basic structure of many other texts extant in the *Libros del Saber de Astronomía*. The King wanted a collection of treatises dealing with the construction and use of astronomical instruments and, for that purpose, he ordered his collaborators to translate the best available Arabic literature on the topic. Books on the use of the instruments were easy to find and this is why most of the treatises of this kind are actual translations of Arabic originals, like that of Qusṭā b. Lūqā. Texts on the construction of instruments were not so common and Alfonso X usually ordered his collaborator Isḥāq ben Sīd (Rabiçag) to write an original work on a specific instrument. The King was also extremely interested in Astrology and, very especially, in *tasyīr* techniques, the main purpose of which is to determine the length of time to pass until a specific event (such as the death of the subject of the horoscope). This interest accounts for the compilation of the *Libro del Ataçir* - which describes a specific astrolabe plate designed for the calculation of the *tasyīr*, projection of rays and division of the houses according to the equatorial method - and the addition of an extra chapter to the *Alcora*, by an otherwise unknown Don Mosheh, which deals with two of the three questions studied in the *Libro del Ataçir*.

The three parts into which the *Alcora* book has been divided are, thus, clear and I will only limit myself to summarize a couple of points which have been developed in detail in this paper. First of all the book seems to be the result of the compilation of three independent works and no attempt has been made to harmonize the whole and avoid repetitions: let us remember the presence of an *armilla menor* (a great circle of longitude) in the construction treatise - following, probably, the model of the *Almagest* - which is not mentioned at all in the treatise on the use of the astrolabe in which the translators do not hesitate to modify Qusṭā b.

Lūqā's original in problems related to the determination of the ecliptical coordinates of a celestial body by using the auxiliary quadrant, but not the *armilla menor*. This is combined with the fact that the auxiliary quadrant, which appears in the treatise on the use of the globe, is described again in Don Mosheh's additional chapter.

Furthermore: even if Qusṭā's book on the use of the celestial globe is the main source used by the Alfonsine authors, and even if the translation is usually faithful to the Arabic original, the translators and authors of this collective work do not consider fidelity as their main purpose. It is very clear that they seek to improve on their sources and offer the King the best possible instrument they are able to describe. There is, no doubt, a certain spirit of originality in Alfonsine scientific works - for which there are clear precedents in twelfth century Latin translations - which will culminate in the *Alfonsine Tables*.