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On the Liber de wazalkora, A 12th-Century Treatise on the Astrolabe

C. Philipp E. Nothaft

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Article abstract

“Liber de wazalkora” is the title of an unpublished Latin treatise on the construction and use of the planispheric astrolabe, which appears to have been compiled in southeast Germany (Bavaria) in the second half of the 12th century. It is to a large extent derived from other astrolabe sources available in the Latin West before 1100, but also contains material that has no precedent in any of the known literature. The analysis presented in this article concentrates on the Liber de wazalkora’s section on the use of the astrolabe, which is unusual for both its extraordinary length and frequently atypical astronomical content. A study of the Arabic loan vocabulary in this section leads to the conclusion that some parts of the text were derived from an unidentified Arabic source, presumably via a Latin intermediary.

On the *Liber de wazalkora*, A 12th-Century Treatise on the Astrolabe

by

C. Philipp E. Nothaft

All Souls College, Oxford
philipp.nothaft@all-souls.ox.ac.uk

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Abstract

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About the Author

C. Philipp E. Nothaft is a £50-fellow at All Souls College, Oxford. He has published widely on the history of astronomy in the Middle Ages, including the recent monograph *Graeco-Arabic Astronomy for Twelfth-Century Latin Readers* (Leiden: Brill, 2023).

Keywords astrolabe, Latin astronomy, 12th century, Arabic-to-Latin translations

1. Introduction

When Paul Kunitzsch (1930–2020) compiled his seminal *Glossar* of Arabic technical terms in medieval Latin sources on the astrolabe [Kunitzsch 1982], he utilized for this purpose 42 different texts, slightly more than one-quarter of which (11) had not yet been printed [Kunitzsch 1982, 466]. One of those that remain unpublished to this day is the anonymous *Liber de wazalkora*, a relatively lengthy work (≈ 10,000 words) covering both the uses and the construction of the planispheric astrolabe. It is extant in two manuscripts, both of which were known to Kunitzsch [1982, 493–494].[1]

> *L* = London, British Library, Arundel 339, ff. 90r–97v (s. XII/XIII)[2]
>
> *M* = Munich, Bayerische Staatsbibliothek, Clm 15957, ff. 11r–32r (s. XII$^{\text{ex}}$) [Möser-Mersky and Mihaliuk 1966, 72].

Liber de wazalkora (hereafter abbreviated as *LW*) is the title found in *L*, while the text itself begins as follows:

> *Spera[m]*[3] *Ptolomei, quam astrolabium vel astrolapsum, seu potius wazalcoram, id est planam speram, appellamus....*

Use of the term “wazalcora” or “wazalkora” (from the Arabic « basṭ al-kura », here meaning the flat projection of the sphere)[4] as a synonym for “astrolabe” is attested in some of the earliest Latin texts devoted to this instrument, which originated in Catalonia in the late 10th century.[5] As pointed out

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[1] The Munich copy had previously been recorded in Zinner 1925, 44, 397 [no. 932].

[2] Juste 2021 provides an extensive bibliography.

[3] “Spera” is the reading in *L* [f. 90r], whereas *M* [f. 11r] has the accusative form “Speram”, as is grammatically correct (*Spera[m] Ptolomei...diligenti rationis inquisitione pertracturi*).

[4] See Kunitzsch 1982, 517–518; Kunitzsch and Lorch 1994, 13 n1; and Borrelli 2008, 167.

[5] See the list of attestations in Kunitzsch 1982, 518 and the remarks in Poulle 2000, 439–440. The principal monographs dealing with the earliest Latin literature on the astrolabe are Millás Vallicrosa 1931 (containing editions of most of the pertinent material); Bergmann 1985; Borst 1989; Puigvert i Planagumà 2000; and Borrelli 2008. A useful bibliography on this subject in provided in Borrelli 2008, 226–266.

in Kunitzsch 1982, 494, most, though not all, of the abundant Arabic loan vocabulary in the *LW* can be explained by the author's exposure to these and other Latin texts that predate the main wave of Arabic to Latin translations of the 12th century. Prominent among these are a treatise on astrolabe use, *De utilitatibus astrolabii* (*ca* 1000?),[6] and Hermann of Reichenau's work on the construction of the astrolabe, *De mensura astrolabii*, which probably dates from the 1040s.[7] These two texts are frequently paired together in manuscripts, to the extent that their combination may be considered the most widely circulated source of knowledge on the astrolabe in the Latin West until the end of the 12th century [see Juste 2016].

Also available to the author of the *LW* was a text known as *Sententie astrolabii*, which belongs to the original 10th-century Catalonian nucleus of this technical literature.[8]

In the remainder of this article, I shall refer to all Latin astrolabe texts written up to and including Hermann of Reichenau's *De mens. astro.* by the collective label "Old Corpus", adopting in this an expression first introduced by Kunitzsch [2000b, 244]. It should be noted that Kunitzsch originally reserved this label for the early Catalonian texts, excluding later elaborations such as *De util. astro.* and Hermann of Reichenau's *De mens. astro.*

Relevant titles not listed there include Martí and Viladrich 1983; Samsó 1991, 2003, 2004a, 2004b, and 2020, 373–399; Poulle 1998, 77–80; Vernet Ginés and Samsó 2004; Schramm, Schütz, Brunold, and Germann 2006–2007; Chlench 2007, 215–231; Viladrich 2009; Zuccato 2010 and 2014; Caiazzo 2012; Juste 2016; Nothaft 2017, 31–36, 229–244 and 2019; Schonhardt 2022, 93–100, 135–146, 190–205; Freudenhammer 2020; and Burnett 2022, 446, 456–457, 473.

[6] Inc.: *Quicunque astronomicae discere peritiam*.... Edition in Bubnov 1899, 109–147. For a bibliography and list of manuscripts, see Jullien 2010, 138–142. The attribution of this text to Gerbert of Aurillac, which was upheld in some of the earlier literature, is forcefully rejected by Gautier Dalché [2013, 256–275]. The previous literature on this question is summarized in Materni 2007, 274–282. See also Poulle 1985, 613–617; and 1995, 228–229; and Jacquemard 2006.

[7] Inc. (1): *Her(i)mannus Christi pauperum*.... Inc. (2): *In metienda igitur subtilissime inventionis Ptolomei*.... The most recent edition is Drecker 1931, 203–212.

[8] Inc.: *Quicumque vult scire certas horas*.... Edited in Millás Vallicrosa 1931, 275–288. A slightly different version of the text was edited, on the basis of MS Bern, Burgerbibliothek, 196, ff. 1r–7r, 8r (s. XI$^{1/2}$), in Schramm, Schütz, Brunold, and Germann 2006–2007, 208–247, 258–259 (with German translation).

A cursory look at the content of the *LW* suggests a division into four main parts, which are:

(i) a flowery prologue extolling the virtues of the instrument in question;
(ii) a description of the different parts of the astrolabe and their (Arabic) names;
(iii) instructions on how to use the astrolabe to solve different problems;
(iv) a construction manual.

These sections differ by the degree to which they can be considered independent compositions. In the case of part (iv), we are dealing to a large extent with a liberal rewording of the content of Hermann of Reichenau's *De mens. astro*., which precedes the *LW* in manuscript *M* [see below]. A vastly more complex case is the content of (iii), which provides rules for over 60 different applications of the instrument. While roughly half of these rules have an identifiable origin in the aforementioned Old Corpus, the remaining ones show no signs of depending on these or any other known Latin texts and accordingly pose some interesting source-critical questions.

In the present article, I seek to make first steps toward raising and addressing some of these questions. I shall begin with a discussion of the date and geographic origin of the *LW*, which I suggest was probably produced in southeast Germany (Bavaria) in the second half of the 12th century. My discussion of this question will also incorporate observations on the content and key characteristics of parts (i), (ii), and (iv) identified above. Next, I shall concentrate in more detail on part (iii), setting out its structure and discussing, where possible, the underlying sources. A separate section will address the use in this part of certain Arabic loanwords as well as the problems raised by the technical content of relevant passages. As I shall suggest, some of these problems may point to the use of an unidentified translation of an Arabic text. Two more sections of the present article will be dedicated to some of the unusual astronomical content of part (iii), which includes—in this context surprisingly accurate—information about the declination of the star Benetnasch (η Ursae Majoris) and some unparalleled doctrines about the latitude and nodes of the Moon.

2. Origin, date, and some general characteristics

L is a parchment codex (198 × 140 mm) from a single hand, written in the late 12th or early 13th century.[9] The manuscript is today best known

[9] See the description in Juste 2021, which provides an extensive bibliography.

for its constellation drawings, which accompany a copy of Hyginus' *De astronomia* on ff. 71v–89v.[10] Its 153 folios are in fact devoted exclusively to texts associated with the quadrivium, culminating in a copy of Macrobius' *Commentarii in somnium Scipionis* [ff. 121r–151r]. The verso side of the final page of this copy preserves, as a later addition, a list of the first seven abbots of the Benedictine abbey of Kastl (1103–1803, now defunct) in the Upper Palatinate, which finishes with the death of abbot Gebhard of Rieden on 12 September 1222. Kastl is here identified as the book's present location (*huius loci*), which invites the conclusion that *L* was either produced at this monastery to begin with or had arrived there by the year 1222.[11]

The other codex, *M*, came to Munich from St Peter's Abbey, Salzburg. It numbers 32 folios (285 × 200 mm) and originally transmitted no more than two different texts: Hermann of Reichenau's *De mensura astrolabii* [ff. 3r–10v] and the *LW*, in copies that appear to date from the late 12th century.[12] A later date seems to be precluded by the fact that the codex was, in all likelihood, mentioned in the 12th-century library catalog of St Peter (after 6 June 1164), which records *Heremannus Contractus super astrolabium* among the books kept for school use (*scolares libri istius ecclesie*) [Möser-Mersky and Mihaliuk 1966, 72]. *M* is thus roughly contemporaneous with *L* and may well be the earlier of the two. Both are seriously corrupt as far as the preservation of their text is concerned.

While one must be careful to distinguish the provenance of a text from its actual origin, the available evidence for the *LW* thus appears to point to a Bavarian or southeastern German background. This hypothesis draws some added plausibility from the fact that texts on the astrolabe are known to have been studied and shared between monasteries in this region since the middle decades of the 11th century.[13] A major center for this activity was St Emmeram's Abbey, Regensburg, where local interest in astronomy led to

[10] See Blume, Haffner, and Metzger 2012, 302–307, which assigns to the manuscript a date around 1200. The date given by Kunitzsch [1982, 494] is "vielleicht 14. Jh".

[11] This list was reproduced as *Catalogus abbatum Castellensium* in Holder-Egger 1881, 337.

[12] See the description in Hauke 1982, 815–816. The date given by Kunitzsch [1982, 494] is "12. Jh. [?]".

[13] For an illuminating study of the scientific, including astronomical, activities in monasteries in southeast Germany during the 11th and 12th centuries, see Schonhardt 2022. For the wider context, see Thomson 2007.

the construction of a stone instrument sometimes known as the *sphaera* of St Emmeram. It is thought to have originated in the second half of the 11th century, perhaps as early as the 1050s.[14] St Emmeram's role as a site of astronomical study could explain how knowledge of the astrolabe first reached Kastl or how the *LW* itself became available at this monastery.

This tentative conclusion about the *LW*'s region of origin is not supported, but also not definitively negated, by the only place-name explicitly mentioned in the text. We are told in part (iii) that Cremona is situated at a latitude of 45°, such that at the two equinoxes the noon shadow in this city will be equiumbral.[15] This geographic reference is generic in the sense that it could have easily been derived from the astronomical literature available at the time of writing. A latitude of 45° is in fact routinely mentioned in the headings to a table of oblique ascensions for Cremona, which by the late 12th century had begun to circulate as part of the so-called Toledan Tables.[16] Their availability in southeast Germany at that time is evinced by MS Munich, Bayerische Staatsbibliothek, Clm 18927, where the ascension table in question appears on f. 21r–v. The latitude of Cremona is here given, incorrectly, as 44° on the recto page but as 45° on the verso page. Clm 18927 originated in the late 12th century and came to Munich from the library of Tegernsee Abbey in Upper Bavaria.[17]

While it is imaginable that the isolated reference to Cremona in part (iii) is the result of a later interpolation into a much earlier text, there are other considerations that support placing the *LW* in a late 12th-century

[14] The best available account of this instrument and the associated scientific activities of William of Hirsau is Schonhardt 2022, 189–296, with edition and German translation of the relevant textual material on pp. 307–331. On the same subject, also see Wiesenbach 1991, 135–142 and 1996; Borrelli 2008, 201; Dekker 2013, 200; Jacquemard 2015; and Hedenus 2015.

[15] *L* f. 94v: *Cremona XLV graduum dicitur, in qua civitate umbram medii diei Libre vel Arietis inde equalem invenies*. Kunitzsch [1982, 494] did not draw conclusions from this passage beyond rejecting a connection with Gerard of Cremona and instead suggesting "andere, vermutlich jüngere Zusammenhänge".

[16] See Pedersen 2002, 1004–1010 (BD20). Copies of this table that are not recorded by Pedersen include MSS Naples, Biblioteca Nazionale, VIII.C.49, ff. 58v–59r (Italy; s. XIII^{ex}; omits columns for hour lengths); Vatican City, Biblioteca Apostolica Vaticana, Vat. lat. 5714, ff. 36r–37v (northern Italy; s. XIII$^{2/2}$); Vatican City, Biblioteca Apostolica Vaticana, Pal. lat. 1410, ff. 48v–50r (France; s. XIII$^{2/2}$). For another 12th-century source (*ca* 1191) mentioning Cremona's latitude as 45°, see Nothaft 2014, 124.

[17] See the description and bibliography for this manuscript in Juste 2022.

context. One of these stems from part (i), the work's prologue, which praises the astrolabe as a tool highly useful in casting astrological judgments, a process that is here dubbed *perfectio iudicandi* and characterized as the chief aim of astronomy (*que precipue in iudicandi perfectione consistit*). The author elaborates upon this idea by citing an "astrologers' claim" (*assertio astrologorum*) according to which all things below are subject to the rule of the celestial bodies. In the same sentence, he highlights the crucial service an astrolabe is apt to provide in obtaining specific astrological parameters such as the Lot of Fortune (*pars fortune*) and, more generally, the positions of the signs relative to the horizon (*emersio signorum*) and the locations of the planets on the ecliptic (*locatio planetarum*).[18]

What makes these remarks especially relevant is that discussions or acknowledgments of astrological uses of the astrolabe are all but completely absent from Latin astrolabe texts written before 1100. A slight exception in this regard is *Ad intimas summe philosophie disciplinas…*, a prologue associated with the earliest layer of the Old Corpus in which astrological beliefs are mentioned and swiftly condemned.[19] It is only in the 12th century, which witnessed a substantial new wave of Latin treatises on the astrolabe, that astrology became a more prominent feature of this literature.[20] The astrological purpose of wielding an astrolabe receives particular emphasis in the *Tractatus astrolabii* by Raymond of Marseilles, which was written in or shortly before 1141 and is largely independent of the Old Corpus.[21]

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[18] *L* f. 90r:

> *Nichil est astronomice subtilitatis, que precipue in iudicandi perfectione consistit, ad quod artis vel potius instrumenti istius facultatem vera indagandi solertia umquam abesse paciatur. Si enim, iuxta assertionem astrologorum, cuncta inferiora nutu superiorum continentur, disponuntur et discurrunt nec ratio signorum, verbi gratia emersio signorum, locatio planetarum, que duo principalis existunt regula iudicandi, pars etiam fortune ubi cadat, preter astrolabium nullus apprehendet, perfectionem astronomice speculationis huic instrumento specialiter inniti manifestum est.*

[19] See the edition in Millás Vallicrosa 1931, 273.68–74. On this text, see also Borst 1989, 67–68; Juste 2007, 246–249; and Borrelli 2008, 168–171.

[20] On the Latin astrolabe literature of the 12th century, see Poulle 1954, 84–90; 1972, 33–36; 1987 and 1998, 80–83; Kunitzsch 1982, 483–503; and Borrelli 2008, 216–218, 240–241. On the 12th-century resurgence of astrology in the Latin West, see d'Alverny 1967; Lipton 1978; and Runciman 2019.

[21] Inc.: *Vite presentis indutias silentio preterire….* Edited in Poulle 1964, 874–900, and

Two other prominent midcentury writers who reserved ample space for astrology in their treatises on the instrument were Adelard of Bath (*De op. astrol.*, 1149/50)[22] and Abraham Ibn Ezra (*ca* 1150?), who composed his Latin work *via* dictate.[23]

Chronologically prior to these contributions were the Latin versions of an Arabic treatise on astrolabe use by Ibn al-Ṣaffār (d. 1035). Two such translations were carried out independently by John of Seville and Plato of Tivoli, both of whom were active in the 1130s.[24] Chapters on astrolabe use also appear in the pseudo-Hermetic *De sex rerum principiis* (after 1147), a cosmological text with a strong astrological orientation,[25] and in an anonymous work on practical geometry starting *Artis cuiuslibet consummatio*..., which contains a reference to the year 1193.[26] Two further sources from this period that pay attention to the instrument's astrological applications, and that remain unprinted, are a treatise on use by Robert of Chester (*Liber de officio astrolabii*, *ca* 1150)[27] and a comprehensive work on both construction and

again, with a French translation, in d'Alverny, Burnett, and Poulle 2009, 50–111. Additional manuscripts are examined in Caiazzo and Burnett 2011.

22 Inc.: *Quod regalis generis nobilitas artium liberalium*.... Edited in Dickey 1982, 147–229. Discussion in Poulle 1987. See also the text beginning *Astrolabiorum igitur sex sunt species*..., which is edited and discussed in Kunitzsch 1994. It is probably related to Adelard's work.

23 Inc.: *Genera astrolabiorum duo sunt*.... Edited in Millás Vallicrosa 1940, 9–29. Discussion in Millás Vallicrosa 1944; Samsó 2012, 189–191 and 2020, 414–417; and Rodríguez Arribas 2014, 249–258.

24 John of Seville's translation is printed in Millás Vallicrosa 1942, 261–284, on the basis of MS Madrid, Biblioteca nacional de España, 10053, ff. 112ra–117vb (s. XIII$^{2/2}$), and (for c. 1) MS Toledo, Archivo y Biblioteca Capítulares, 98–27, ff. 48v–49r (s. XV). It was the main source for the popular *Practica astrolabii* attributed to Māshā'allāh, as is demonstrated in Kunitzsch 1981, 48–56. Plato of Tivoli's translation is edited in Lorch, Brey, Kirschner, and Schöner 1994, 138–174. An anonymous and incomplete third translation is analyzed and edited in Nothaft 2023. A recension of the Arabic text is printed in Millás Vallicrosa 1955, 47–76 (Arabic section) and translated into Catalan in Millás Vallicrosa 1931, 29–48.

25 Pseudo-Hermes, *De sex rerum principiis* 23–32 [Lucentini and Delp 2006, 205–211].

26 Edition and English translation in Victor 1979, 108–471. For chapters involving the astrolabe, see 2.9, 13, 19, 21–24, 29–31, 36 [Victor 1979, 238–239, 246–247, 264–265, 268–275, 292–301, 317–318].

27 Inc.: *Incipiunt capitula: de gradus Solis per diem et diei per gradum Solis inventione*.... This unpublished text is extant in MSS Milan, Biblioteca Ambrosiana, H 109

use attributed to a certain Arialdus, which can be dated only approximately to the second half of the 12th century.[28]

Certain hints that place the *LW* closer in time to these texts than to the Old Corpus also appear in part (ii), which surveys the different components of the astrolabe and provides their Arabic names. While most of the technical vocabulary introduced in this section goes back to the Old Corpus, there are also some exceptions with a potential bearing on the dating of the text.[29] A confusing case of this nature is "malgaria", a name given to a spike or spine (*spina*) that supposedly goes through the horse-shaped wedge or *alferaz*—from Arabic « al-faras » (the horse)—that was traditionally used to secure the central pin holding together the different parts of the instrument.[30] Kunitzsch judged it unidentifiable.[31] Far more familiar is the expression "mater", which is used twice in part (ii) to refer to the main plate carrying the remaining disks.[32] This now-standard expression, which is a calque of the Arabic « 'umm », does not yet appear in texts of the Old Corpus. Rather, its entry points into Latin astrolabe literature were the translations of Ibn al-Ṣaffār's use treatise, carried out, approximately, in the 1130s.[33] Two independent writers who used the term early on were Raymond of

sup., ff. 9v–17v (pages missing; s. XV); Oxford, Bodleian Library, Canon. misc. 61, ff. 12r–22v (s. XV). See Kunitzsch 1982, 492.

28 Inc.: *Cum inter omnia instrumentorum genera*.... This unpublished text is extant in MSS Cambridge, Jesus College, Q.G.29, ff. 187r–190r (incomplete; s. XII$^{2/2}$); Paris, Bibliothèque nationale de France, lat. 16652, ff. 28r–37v (s. XIII$^{1/2}$). See Poulle 1954, 87–88; 1956, 311–312 and 1972, 34–35; Kunitzsch 1982, 492–493.

29 See Kunitzsch 1982, 494–495, which also discusses a brief glossary of Arabic terms that was added to the left margin of *L* f. 94v. In what follows, I shall underline any Arabic loan words that appear in quotations from the *LW*.

30 *L* f. 91r: *Clavis tabularum qui in alcitop superius locatur alferaz vel pegasus dicitur ipsumque pegasum transiens quasi spina quedam malgaria nominatur*.

31 See Kunitzsch 1982, 521 ("nicht identifizierbaren Namen").

32 *L* f. 90r–v: *Tabula ea que ceteras [*L*: cum] in se continet mater appellatur, cuius anterior pars antica, posterior postica vocari debebit.*
Also *L* f. 90v:

> *In ipsa etiam matre climatum incluse tabule sunt tres. Nam ipsa mater tabula primum in se, prima reliquarum secundum et tertium, secunda quartum et quintum, tertia sextum et septimum clima continebit.*

33 Ibn al-Ṣaffār, *Kitāb fī-l-ʿamal bi-l-asṭurlāb*, trans. John of Seville, c. 1 [Millás Vallicrosa 1942, 263]; trans. Plato of Tivoli, c. 1 [Lorch, Brey, Kirschner, and Schöner

Marseilles (*ca* 1141) and Rudolf of Bruges (after 24 April 1144).[34] The *LW* happens to converge with Rudolf's text in another minor respect, which is that both refer to the alidade as a *linea*, which is otherwise uncommon.[35]

Another term that may be worth remarking upon is the diminutive form "reticulum" (literally denoting a small net or web) as an alternative label for the rete. This word appears once in the Latin astrolabe treatise by Abraham Ibn Ezra, which can be dated only approximately to the years around 1150.[33] In addition, it can be found in a short text on astrolabe construction that was printed among the works of the Venerable Bede in 1563.[34] While the first part of this so-called *Libellus de astrolabio* was excerpted from the Old Corpus text known as *De mensura astrolapsus*, no manuscript corresponding to the remaining parts, which include a section headed *De reticuli mensura*,[35] has so far been identified. The immediately preceding section (*De dispositione climatum*) identifies the author's own latitude (*nostrum clima*) as 49°, which, coincidence or not, matches the approximate latitudes of Regensburg (49;1°) and Kastl (49;22°).[36]

1994, 139.39–40]. See also John of Seville, *Dixit Iohannes: Cum volueris facere astrolabium*.... [Millás Vallicrosa 1942, 322, 325–326].

34 Raymond of Marseilles, *Tract. astro*. 2a–b, 3a, 8 [d'Alverny, Burnett, and Poulle 2009, 56, 60, 80]; and *Liber cursuum planetarum* 1.92b [d'Alverny, Burnett, and Poulle 2009, 192]; Rudolf of Bruges, *Cum celestium sperarum diversam positionem*... c. 1 [Lorch 1999, 60]. See also Abraham Ibn Ezra, *Genera astrolabiorum*... [Millás Vallicrosa 1940, 9] and Arialdus, *Cum inter omnia*... [MS Paris, Bibliothèque nationale de France, lat. 16652, f. 32r].

35 *L* f. 91r: *Seorsum sane astrolabii ea linea circuit quam curriculum vel mediclinium vel cursorem Latine, alhidada Arabice nuncupamus*. Cf. Rudolf of Bruges, *Cum celestium*... c. 5 [Lorch 1999, 63]. This agreement was previously noted by Kunitzsch 1982, 494.

33 Abraham Ibn Ezra, *Genera astrolabiorum*.... [Millás Vallicrosa 1940, 9–10].

34 Herwagen 1563, 467–470 = Migne 1862 (PL 90), 955D–960A. See Bergmann 1985, 96–99.

35 Herwagen 1563, col. 470 = Migne 1862 (PL 90), col. 958D.

36 Herwagen 1563, col. 470 = Migne 1862 (PL 90), col. 957C.

Hermann of Reichenau *De mensura astrolabii* c. 4*	*Liber de wazalkora* [*L* f. 96r]
Descriptis primo in tabula ejus aliquantum spissiora, tribus circulis ejusdem cujus et supra quantitatis, aequinoctiali videlicet, hiemali atque aestivo solsticialibus, eodemque modo lineis rectis, quas coluros dixi, in quatuor aequa, ut supra, divisis, colurum unum versus meridiem a septentrione directum a puncto ubi aestivum minimum secat usque ad punctum ubi ex opposito jungitur maximo hiemali circulo in duo divide et centro in medio fixo zodiacum circulum, in quo tota hujus artis consistit efficacitas, ita circumscribe, ut minimum totum infra se continens circulum ex una ei parte conjungatur, ex opposita per diametrum parte maximo adunetur mediumque circulum altrinsecus simul et alium colurum ad singula puncta intersecet atque per ipsius coluri lineam in bina emisphaeria, sed non aequaliter dividatur. Ipsi quoque congruam latitudinem, in qua nomina duodecim signorum et quarundam stellarum inscribi possint, ad libitum tribue.	Descriptis igitur in tabula, priusquam pertusetur et perforetur, tribus, ut iam antedictum est, circulis, maximo, medio et minimo, sic ut equales sint ipsi circuli ad circulos dudum factos in almucantarat, et coluris eosdem, ut ante, circulis secantibus, colurum qui a septentrione porrigitur versus meridiem etiam a puncto ubi minimum estivum circulum secare incipit usque ad punctum ubi maximo hiemali coniungitur in duo equa dividito spacia centroque in medietate fixo circulum circumducito, qui zodiacus nominatur, in quo tota artis huius consistit efficatia, ita ut minimum intra se totum circulum contineat cui et una ex parte coniungatur, ex opposito ad maximum adunetur hiemalem circulum, medium autem equinoctialem circulum ad certa altrinsecus puncta intersecet et per colurum ab oriente deductum in occidentem circulus ipse iam factus, zodiacus dico, secetur, haut tamen equaliter. Latitudinem porro ipsi circulo ad libitum, spaciis tamen circuli ipsius congruentem ubi XII inscribantur, attribue.

Table 1.

* Drecker 1931, 207 with some slight changes to the interpunctuation.

In the *LW*, the word "reticulum" is deployed twice, once in part (ii) and a second time in the construction treatise that makes up part (iv).[37] As mentioned in the introduction, the main model that served in composing the latter part was Hermann of Reichenau's *De mens. astro*. The verbal overlap between this source text and the *LW* is substantial, as may be seen in Table 1, p. 12 above, which compares their respective descriptions of the circles on the rete (words in Hermann's text that reappear in the *LW* are in red print).

Given the demonstrable dependence on Hermann's treatise, it should come as no surprise that the plan of astrolabe construction offered in the *LW* is to a large extent the same as that attested across different Old Corpus texts and the associated drawings.[38] For instance, the horizon plates of the astrolabe known to the author of the *LW* carried almucantars (lines of equal altitude) and hour lines but no azimuth curves. Rather than being inscribed for the latitude of specific cities, the plates catered to the seven ancient climates. We are specifically told that the first of these climates is represented on the inside of the mater, the remaining six on the opposing sides of the three plates.[39] The placement of star pointers on the rete depended on a widely circulated list of 27 star names and their coordinates, which is appended to the text in *L*. Its data are for the most part rooted, via another Arabic

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37 *L* f. 91r:

> *Preter eas quas dixi tabulas almucantarat est tabula superior omnium pertusione perforata, que reticulum seu volvellum, vel potius Arabice alhancabuth nominatur.*

L f. 97r:

> *Post omnia id cautissime perspicies qualiter lineam vachadib inkoantem [*sic*] a fine Piscium et pertingentem usque ad principium Libre deducas, que linea omnium alhancabuth circulorum conexoria, quod sine ea partes ipsius reticuli nequaquam coherent, non indigne vocari valebit.*

38 For a discussion of one such set of drawings, see Kunitzsch 1998. On the astrolabe design in Old Corpus texts and some of the changes introduced in the 12th century, see the remarks in Poulle 1955; 1972, 27–36; and 1995.

39 *L* f. 90v:

> *In ipsa etiam matre climatum incluse tabule sunt tres. Nam ipsa mater tabula primum in se, prima reliquarum secundum et tertium, secunda quartum et quintum, tertia sextum et septimum clima continebit.*

intermediary, in a star table that was originally created by Maslama al-Majrīṭī in 978.[40] In the case of the *LW*, the immediate source was probably once again Hermann of Reichenau, as suggested by the layout, the spelling of certain stars' names, and a shared error in one of the coordinates of the star Alhabor [see p. 42 below].

Hermann's influence on the astrolabe design presupposed in our text also manifests itself in part (iii), which deals with the astrolabe's uses. Two different chapters of this part [§§40 and 50 according to the division introduced below] argue that at the equator (*in medio mundi*) each zodiacal sign rises with the same number of degrees shown on the rim.[41] This incorrect assumption about the right ascension of the signs harmonizes with the way the division of the ecliptic on the rete is described in part (iv), where the number of degrees on the outer rim assigned to each sign on the rete is 30°.[42] Only Hermann's text and an earlier treatise on astrolabe construction by Ascelinus of Augsburg prescribe this simplified method of dividing the

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[40] The star list in question is Type III edited in Kunitzsch 1966, 23–30. Its origin and diffusion are discussed in Bergmann 1980, 75–97; Kunitzsch 1999–2000 and 2000a; Samsó 2000; 2004a, 127–132; and 2020, 382–387. The revisionist argument in Zuccato 2010 is unconvincing.

[41] *L* f. 93r:

> *In medio mundi non singulum signum cum singulis gradibus, sed omnia cum pari numero graduum oriuntur. Verbi gratia, pone primum gradum cuiusque signi ad lineam medii celi et signa ad almuri. Pone in eodem loco ultimum eius gradum. Nota et quotos inter notas ipsas gradus reperies. Cum tot omnia oriuntur cetera signa gradibus.*

L f. 93v:

> *Solum ei qui esset in medio mundi ascensiones ipse essent omnes equales.*

[42] *L* f. 96r–v:

> *Deinde spacia XII signorum hoc modo permeties ut maximo trium circulorum in XII diviso equales partes regulam in centro trium circulorum et in cuiusque de XII spaciorum signis limite ortogonaliter appones. Ubi ipsa regula zodiacum nuperrime factum circulum tangat diligenter assignes et ita secundum spacia XII in hiemali circulo XII zodiaci circuli signorum spacia reperisti. Non tamen equa, nam in minoris emisperii spacio totidem locata habebis quota in maiori constare perspicis.*

ecliptic,[43] whereas other Old Corpus texts acknowledge, at least implicitly, that the right ascensions of the 12 signs must be unequal.[44]

Other than the alidade, the only other features that the *LW* locates on the astrolabe's backplate are a shadow square and some concentric circular scales for the zodiac and the dates of the Julian calendar. In this regard, our text once again conforms to the relatively limited design described in Old Corpus texts. The only real surprise comes in the guise of some comments about "Saracen astrolabes" (*astrolabia Sarracenica*), that is, astrolabes carrying Arabic rather than Latin inscriptions for numbers and the names of the months and zodiacal signs.[45] It seems possible that these references about astrolabes with Arabic inscriptions were inspired, not by any physical instruments the author might have seen but by the availability of drawings such as those preserved in the 11th-century MS Paris, Bibliothèque nationale de France, lat. 7412, ff. 19r–23v, which depicts the rete, horizon plates, and backplate of an Andalusian astrolabe made by Khalaf ibn al-Muʿādh.[46] What remains difficult to explain, however, is a statement made in part (iv), according to which astrolabes of the Saracen type are uniquely characterized by the addition of a scale of 360° to the outer rim of the backplate. The implication here seems to be that Latin astrolabes ordinarily come without such a

43 Hermann of Reichenau, *De mens. astro.* c. 5 [Drecker 1931, 207–208]; Ascelinus of Augsburg, *Compositio astrolabii* [Burnett 1998, 348].

44 See on this point Borrelli 2008, 137–157 and the earlier discussions in Poulle 1955, 121–122; 1972, 29–32; 1995, 234–235; and Viladrich and Martí 1981, 89–94.

45 *L* f. 90r–v:

> *Quedam sane Latina, quedam Sarracenica fore constat astrolabia, et utraque certe formaturas linearum vel circulorum, numeros tabularum quoque eosdem habere probantur, apices porro numerorum vel nomina stellarum signorumve diverse nimirum iuxta idioma Latini vel Sarracenici insculpta existunt.... Ut autem a postica convertar ad anticam, primo labium vel umbonem consideremus astrolabii, quem Arabes algozam nominant, ubi linee minuscule itemque grandiuscule per circuitum disposite numerum CCCLX complent, quas lineas in tribulationibus numerorum Sarracenicis nonnulla astrolabia insculpta referent.*

46 For discussions of these drawings, see Poulle 1995, 230–231; Kunitzsch 1998; Borrelli 2008, 203–210; Samsó 2020, 373–375. Another such set of drawings appears in MS Bern, Burgerbibliothek, 196, ff. 1v, 2r, 3r, 7v [s. $XI^{1/2}$; reproductions in Schramm, Schütz, Brunold, and Germann 2006–2007, 207, 284, 286–287, 289, 298].

scale, which is implausible given its relevance to the altitude measurements performed with the alidade and repeatedly described in the *LW*.[47]

3. The "use" part: structure and sources

From a historical and source-critical perspective, the most valuable and complex segment of the *LW* is probably part (iii), on astrolabe use, which is going to be the focus of the remainder of this study. It poses some interesting challenges in the sense that the rules for astrolabe use presented here are in many instances not reducible to what is found in comparable texts from the Old Corpus (the *Sent. astro.* and *De util. astro.*), or even in astrolabe texts written during the 12th century. The following outline of part (iii) seeks to provide a rough idea of its content as well as to facilitate references to the text in the following discussions. My division of this part into 68 sections or "chapters", some of them as short as a sentence, prioritizes logical units of content and is therefore not very strictly aligned with the divisions indicated in the two manuscripts. Where the section in question has a close counterpart in one or more Old Corpus texts, this will be noted in the corresponding footnote.

(1) Memorizing the latitudes of the seven climates;[48]
(2) Discerning the climate of a horizon plate;
(3) Finding the degree of the Sun from the known calendar date using the alidade and backplate;[49]
(4) Finding the degree of the Sun from the known calendar date using a computational formula;[50]

[47] *L* f. 97r:

> *Postica wazalkore sola restat metienda, in cuius ambitu primum ducatur circulus qui tamen in solis sit Sarracenis astrolabiis.... Hoc autem summus et ceterorum inclusivus circulorum in quarter XC, eadem qua superius iam dictum est ratione, divisus gradus solarium ascensionum vel descensionum curriculo, hoc est alhidada, apprehendente signamus.*

[48] *Regule de quarta parte astrolabii* [Millás Vallicrosa 1931, 307.52–58]; *De divisione igitur climatum....* [Millás Vallicrosa 1931, 321.39–43]; *De util. astro.* 18.2 [Bubnov 1899, 141.2–7].

[49] *Sent. astro.* [Millás Vallicrosa 1931, 282.196–201]; *De util. astro.* 3.4 [Bubnov 1899, 126–127].

[50] *Sent. astro.* [Millás Vallicrosa 1931, 282.186–196]; *De util. astro.* 3.3 [Bubnov 1899, 126].

(5) Locating the Sun's nadir using the alidade;[51]
(6) Locating the Sun's nadir using a mnemonic;
(7) Measuring solar altitude using the alidade;[52]
(8) Finding the hour during daytime from the solar altitude;[53]
(9) Finding the current part of the hour;[54]
(10) Using the change in solar altitude to decide whether it is before or after noon;[55]
(11) Computing the solar noon altitude of a given day;[56]
(12) Computing the change in solar noon altitude for a given month;[57]
(13) Finding the direction of the meridian from the measured solar altitude;
(14) Finding local latitude via the equinoctial solar noon altitude;[58]
(15) Measuring hours of daylight on the backplate using the alidade;[59]
(16) On the relation between the 12 hours of the day and the four directions;[60]
(17) Finding the hour during nighttime from the stellar altitude;[61]
(18) Whether a given star is currently rising or setting;
(19) Finding the ascending sign or degree;[62]

[51] *De util. astro.* 4.2–3 [Bubnov 1899, 127–128].

[52] *Sent. astro.* [Millás Vallicrosa 1931, 280.127–133]; *De util. astro.* 5.2 [Bubnov 1899, 128–129].

[53] *Sent. astro.* [Millás Vallicrosa 1931, 280.137–281.157]; *De uti. astro.* 5.3 [Bubnov 1899, 129].

[54] *Sent. astro.* [Millás Vallicrosa 1931, 283.203–208, 287.353–363]; *De util. astro.* 9 [Bubnov 1899, 133].

[55] *De util. astro.* 20 [Bubnov 1899, 146–147].

[56] *De altitudine solis* [Millás Vallicrosa 1931, 292.41–48].

[57] Millás Vallicrosa 1931, 292.41–48.

[58] *Sent. astro.* [Millás Vallicrosa 1931, 287.365–371]; *Sumpto astrolapsu in meridie....* [Millás Vallicrosa 1931, 308.84–90]; *De divisione igitur climatum....* [Millás Vallicrosa 1931, 321.31–35]; *De util. astro.* 18.2 [Bubnov 1899, 140].

[59] *De util. astro.* 21 [Bubnov 1899, 147].

[60] *De util. astro.* 7 [Bubnov 1899, 131].

[61] *Sent. astro.* [Millás Vallicrosa 1931, 281–282.160–184]; *De util. astro.* 6.3 [Bubnov 1899, 130–131].

[62] *Sent. astro.* [Millás Vallicrosa 1931, 286–287.326–344]; *De util. astro.* 15 [Bubnov 1899, 135–136].

(20) Computing the arc of daylight or nighttime;[63]
(21) On the natural *vs* artificial hour;[64]
(22) Deriving the length of the hour of the night from length of the daytime hour and *vice versa*;[65]
(23) Reminder: at the equinoxes, day and night are equal and each consists of 12 natural hours;[66]
(24) Reminder: daytime hours are measured with the nadir, nighttime hours with the Sun;[67]
(25) Computing the length of (artificial) daytime or nighttime hours;[68]
(26) On the hour lengths at the solstices;
(27) Finding the number of equal hours contained in the arc of daylight;[69]
(28) Deriving the length of the artificial daytime hours from the arc of daylight;[70]
(29) Using the measured altitude of a planet to find the hour during nighttime;
(30) Computing the maximum altitude of a fixed star;
(31) Finding the degree (= mediation) of a fixed star;[71]
(32) Using stellar altitudes to test an astrolabe's accuracy;
(33) Determining the beginning/end of twilight;[72]

[63] *Sent. astro.* [Millás Vallicrosa 1931, 283–284.226–237]; *De util. astro.* 11–12 [Bubnov 1899, 133–134].

[64] *De util. astro.* 8.2–3 [Bubnov 1899, 132].

[65] *Sent. astro.* [Millás Vallicrosa 1931, 283.216–224]; *De util. astro.* 10 [Bubnov 1899, 133].

[66] *Sent. astro.* [Millás Vallicrosa 1931, 284–285.259–271]; *De util. astro.* 8.3 [Bubnov 1899, 132].

[67] *Sent. astro.* [Millás Vallicrosa 1931, 282.182–184; 283.215–216]; *De util. astro.* 6, 10 [Bubnov 1899, 131.2–3, 133.11–12].

[68] *Sent. astro.* [Millás Vallicrosa 1931, 283.203–216]; *De util. astro.* 9–10 [Bubnov 1899, 133].

[69] *Sent. astro.* [Millás Vallicrosa 1931, 284–285.251–259]; *De util. astro.* 13.1 [Bubnov 1899, 134].

[70] *Sent. astro.* [Millás Vallicrosa 1931, 284.246–249].

[71] *Sent. astro.* [Millás Vallicrosa 1931, 286.306–310]; *De util. astro.* 16 [Bubnov 1899, 136].

[72] *Sent. astro.* [Millás Vallicrosa 1931, 287.346–351]; *De util. astro.* 14 [Bubnov 1899, 135].

(34) Distinguishing a planet from a fixed star;
(35) Computing the ascensional degrees of a zodiacal sign;
(36) Using the solar altitude to find the zodiacal degree of the Moon during daytime;
(37) Using the lunar meridian altitude to determine local distance from the two tropics;
(38) Measuring the zenith distance of the Sun at noon;
(39) Calculating the latitudinal difference between two locations;
(40) On the ascensions of the zodiacal signs at the equator;
(41) Telling the relative locations (north/south) of two cities from their latitudes;
(42) Using the altitudes of a circumpolar star to determine local latitude;
(43) Using the solar noon altitude to infer the calendrical date;[73]
(44) Using the altitude of a fixed star to find the zodiacal degree of the Moon during nighttime;
(45) Determining the position of the present climate with respect to the boundaries of the torrid zone;
(46) Identifying the stars located within a given zodiacal sign;
(47) Using the culmination of a star to locate the meridian;
(48) Using the degree of a star on the meridian to identify the boundaries of its zodiacal sign;
(49) Calculating the distance between two stars (in degrees of altitude);
(50) Finding the right and oblique ascensions of the zodiacal signs;
(51) Using the lunar meridian altitude to measure the local latitude;
(52) Finding local latitude on any given day *via* the solar noon altitude and declination;
(53) Determining the declination of a zodiacal degree;
(54) Deciding which of two visible stars is closer to one's zenith;
(55) Finding the declination (*latitudo*) of a star;
(56) Using the lunar and solar altitudes to measure the latitudinal width of the zodiac;
(57) Finding the local latitude or position of the celestial equator from two complementary solar noon altitudes;
(58) Finding the four directions using a shadow;
(59) Estimating local latitude at the equinoxes using a shadow;

[73] *Sent. astro.* [Millás Vallicrosa 1931, 286.312–324].

(60) Finding the direction (*assumuth*) of a city from one's current position;
(61) Finding the distance of one's current location from the prime meridian (*naturalis meridies*);
(62) Locating the five parallels if one is directly "below the meridian line" (*sub linea meridiana*);[74]
(63) Locating the five parallels if one is not "below the meridian line" (*sub linea meridiana*);
(64) Using the culmination altitude of Benetnasch (η Ursae Majoris) to decide whether one is directly "below the meridian line" (*sub linea meridiana*);
(65) Locating the parallels if one is directly below the tropic of Cancer or equator;
(66) Knowing for each of the seven climates the ever-visible or invisible amount of the northern and southern temperate or frigid zone;
(67) Deriving the distance between one's own zenith and the beginning of the frigid zone;
(68) Finding the zodiacal degree of a planet *via* the altitude of a fixed star.

As can be seen from the brief description of each chapter, the sequence of topics in part (iii) does not follow the most stringent principle of organization. While it is possible to identify certain thematic blocks (for instance, §§20–28 are all in some way concerned with hour lengths), there are also noticeable ruptures as well as repetitions of certain topics. Several chapters in this part, seven in total [§§37, 45, 62–63, 65–67], are concerned with locating five parallel circles in the visible celestial hemisphere or with determining the distance in degrees between these parallels and one's own location. Three of these parallels are the equator [labeled *medium mundi* in §§39–40, 42, 50–51, 57–59, 65] and the tropics of Cancer and Capricorn, which form the northern and southern boundaries of the uninhabitable torrid or "burnt" zone (*perusta*, mentioned in §§1, 37, 45, 62). The other two are the boundaries between the northern and southern temperate zones [*temperata*, mentioned in §§37, 62, 66] and the adjacent uninhabitable frigid zones [*frigida*, mentioned in §§62, 66–67]. Throughout it is assumed that the latter two parallels are each found at 36° from the respective pole. The tropics are found 30° below these circles and are themselves located 24° north and south of the equator [§§45, 51, 62, 67].

This specific division of the heavens and earth as well as the associated terminology were familiar from classical Roman sources such as Macrobius

[74] The meaning of "sub linea meridiana" in this and the following two chapters is left opaque.

(*In somn. Scip.*) and (pseudo-)Hyginus, whose *De ast.* immediately precedes the *LW* in *L*.[75] This pairing of texts is not accidental, seeing as the prologue of the *LW* contrasts the following description of the astrolabe favorably with "the above book, in which the globe is called 'the sphere of Hyginus' (*Eginus*)".[76] Later on, in a passage in part (ii) on the meaning of the term "astrolabe", the author again asserts that Hyginus was the inventor of a celestial globe, which was later improved by Ptolemy through stereographic projection: "What Hyginus invented in the form of a sphere [*globosa*], yet without being fully satisfactory for the purpose of astronomical operations, Ptolemy is known to have set out, not in the round form of a globe, but in a flat form after the manner of circular tablets".[77]

In specifying the distances of the five parallel circles mentioned above, Hyginus relies on a division of the circumference of the entire sphere into 60 *partes*, each of which is the equivalent of 6°. The boundaries between the frigid and temperate zones are hence located 6 *partes* from the respective

75 Macrobius, *In somn. Scip.* 1.15.12–15, 2.5–10 [Willis 1970, 62–63, 110–126]; Hyginus, *De ast.* 1.4–7 [Viré 1992, 5–10].

76 *L* f. 90r:

> *Cumque in superiore libro, quo [*L*: que] globus spera Egini appellatur, non sine multa bene animadvertentium utilitate docuerimus, adeo illi scientie ista supereminet, ut opinionem potius quam rationem in illo instrumento secuti fuerimus respectu istius mirabilis et incredibilis discipline, in qua veritatem cuiusque, ut ita dicam, regule haut aliter quam oculis, quibus precipue fides adhiberi solet, comprobare valebis, natura ipsa palam attestante et quasi proclamante rationem dictorum.*

77 *L* f. 90r:

> *Wazalkora autem, id est plana spera, nominatur, eo quod quam Eginus globosa invenerat haut per omnia operibus astronomie satisfacerentem, eam Ptolomeus non rotundam vice globi, sed planam in modum circularium tabularum instituisse cognoscitur.*

It may be worth noting that Honorius Augustodunensis, in his *De animae exilio et patria* (before 1138), associated Hyginus with the astrolabe. See *De animae exilio et patria* c. 8 [Migne 1854 (PL 172), 1245A]:

> *Septima civitas astronomia, quae deducit ad patriae habitacula. In hac Hyginus per astrolabium incrementa ac decrementa lunae, anfractus, solis planetarum cursus ac recursus ostendit, sphaeram evolvit: in qua signa zodiaci ac caetera monstra coeli per distantes stellas depingit.*

pole, which correspond to a declination of $90° - (6 \times 6°) = 54°$.[78] Rather than accurately designating the declination of the Arctic and Antarctic circles, this value originated in antiquity as the position of the circle of ever-visible stars at a latitude of 36°.[79] In the *LW*, Hyginus' *partes* or segments of 6° reappear as *sexagene* [§§66–67], which are used in §66 to spell out, for each of the seven climates, the ever-visible or ever-invisible amount of the temperate or frigid zones in the northern and southern hemispheres.

The *LW* is, of course, far from unique in adhering to the outlines of Hyginus' "sphere", which had an appreciable influence on astronomical teaching in Latin Europe between the 10th and the 12th centuries. Examples include a letter by Gerbert of Aurillac to Constantine of Fleury (between 972 and 982), which discusses the construction of a hemisphere with sighting tubes,[80] and three anonymous accounts of how to manufacture a celestial globe: *Spera fiat omni parte equalis et rotunda*...,[81] *Inventis in sphaera rotunda coluris*...,[82] and *Speram celi facturus ducas circulum*... (which explicitly references Hyginus).[83] Traces of it are also present in the pseudo-Bedan *De mundi caelestis terrestrisque constitutione liber*, whose 12th-century southern German origin puts it in proximity to the *LW*.[84] More significant still may be

78 Hyginus, *De ast.* 1.7 [Viré 1992, 7–8, ll. 40–73]. See also Macrobius, *In somn. Scip.* 2.6.2–5 [Willis 1970, 116–117].

79 See Wiesenbach 1991, 139–141; Dekker 2013, 31–34.

80 The letter is edited in Bubnov 1899, 24–28; Riché and Callu 1993, ii.680–687 (with French translation) and discussed in Dekker 2013, 194–201. For a bibliography and list of manuscripts, see Jullien 2010, 136–138.

81 This text remains unpublished. Its only known copy is MS London, British Library, Royal 13.A.XI, ff. 118v–119v (s. XI/XII).

82 This text is printed as among the works of Bede in Herwagen 1563, 436–438 = Migne 1862 [PL 90], 940D–942B. See Dekker 2013, 206–207.

83 This text is edited in Cantor 1875, 226–227 on the basis of MS Salzburg, Bibliothek der Erzabtei St Peter, a.V.7, ff. 100v–101r (s. XII) and in Dekker 2013, 202–203 on the basis of MS Darmstadt, Universitäts- und Landesbibliothek, 1020, f. 61v (s. XII$^{1/2}$). Further MSS: Rostock, Universitätsbibliotek, philol. 18, p. 61 (s. XII/XIII); Wrocław, Biblioteka Uniwersytecka, R 55, f. 76r–v (s. XII/XIII).

84 Pseudo-Bede, *De mundi cael.* 1.1.2 [Pradel-Baquerre, Biasi, and Gévaudan 2016, 60]: *Hunc autem per sexagenas diuide et attribue uicinae frigidae sex, temperatae quinque, perustae octo, temperatae ulteriori quinque, frigidae sex.*

On the date and place of origin, see Caiazzo 2002, 147–152; Cécile Biasi and Béatrice Bakhouche in Pradel-Baquerre, Biasi, and Gévaudan 2016, 12–16.

the fact that the very same scheme—with five parallels and a division of the circle into 60 parts—appears on the aforementioned *sphaera* of St Emmeram as well as on a corresponding drawing preserved in MS Munich, Bayerische Staatsbibliothek, Clm 14689, f. 1r (s. XII$^{1/2}$). The evidence suggests that this monument and the drawing were among the outcomes of the astronomical activities of William of Hirsau, who was a monk at St Emmeram before becoming abbot of Hirsau Abbey in 1069. During his time in St Emmeram, William composed a treatise in dialogue form on astronomical instruments (*Astronomia*), of which only the beginning and some further fragments survive [see p. 7 n14 above]. The most recent study of this material is by Michael Schonhardt, who includes a brief text on a celestial globe (*Primum observandum est in spera*...) among the material that may originally stem from William's writings. As with the globe texts mentioned above, this one operates with the structural principles familiar from Hyginus and respected in the *LW*.[85]

Two other sources besides Hyginus that had a detectable influence on the *LW* are the *Sent. astro.* and *De util. astro.*, the two earliest known treatises on astrolabe use. Of the 68 chapters listed above, at least 26 have identifiable counterparts in these Old Corpus texts. In addition, several of the remaining chapters could have been formulated with relative ease by someone familiar with their content. This includes the very basic rules provided in §6 (which is a mnemonic for finding the degree of the nadir), §39 (which uses the degree scale on the backplate for a simple subtraction to determine the difference in latitude between two places), §43 (which uses the measured solar noon altitude to infer the current date), and §49 (which counts the difference in measured altitude between two stars).

Where the author depended on rules expressly given in the *Sententie* and/or *De util. astrol.*, he used these sources very freely, typically rearranging or abbreviating their content or couching it in a substantially different vocabulary. A surprising change occurs in §4, which presents a simple algorithm for converting a calendrical date into a solar degree (based on adding 15 to

[85] Edited in Cantor 1875, 224–225 and Schonhardt 2022, 329–331 (with German translation), on the basis of MS Salzburg, Bibliothek der Erzabtei St Peter, a.V.7, ff. 98r–99v (s. XII). The text is also transmitted in MSS London, British Library, Royal 15.B.IX, ff. 68v–69r (s. XII); Oxford, Jesus College, 4, ff. 92r–v (s. XI/XII); Oxford, Bodleian Library, Digby 191, ff. 77v–78r (s. XIII/XIV); Rostock, Universitätsbibliothek, philol. 18, pp. 59–60 (s. XII/XIII); Wrocław, Biblioteka Uniwersytecka, R 55, ff. 74r–75r (s. XII/XIII).

the current day of the month). This algorithm would be practically identical to what is found in the two texts just mentioned, were it not for the fact that the *LW* changes the example provided from 20 April/5° Taurus to 20 December/5° Capricorn.[86]

Another chapter that seems worth highlighting in this regard is §33, which teaches when to expect the onset of twilight in the morning or its end in the evening. In medieval astrolabes and the associated literature, whether from the Old Corpus or written in the 12th century, the standard limit used for this purpose is a solar depression of 18°.[87] The *LW*, by contrast, mentions this depression angle besides an alternative value of 16°, which is presented as the opinion of "certain people" (*secundum quosdam*). In fact, the concrete example given at the end of §33 operates with this angle of 16° rather than 18° for reasons that are unclear.[88]

A subtle terminological quirk that pervades part (iii) concerns the various references to measurements or computations of horizontal altitude. In *De util. astro.*, the term "altitudo" is ordinarily used in the singular, although in one of its sections "altitudo climatis" refers to the geographic latitude

[86] *L* f. 91v:

> *Verbi gratia, XX dies Decembris hodie transacti sunt. Adde ad hanc summam XV et habes XXXV. Incipe numerare a Sagittario, quod est signum Decembris, et dabis ei XXX. Post Sagittarium Capricornus est et restant etiam V super XXX. Sol XX die Decembris in quinto gradu Capricorni [*L*: Sagittarii] reperitur*.

[87] *Sent. astro.* [Millás Vallicrosa 1931, 287.346–351]; *De util. astro.* 14 [Bubnov 1899, 135]; John of Seville, *Dixit Iohannes…* [Millás Vallicrosa 1942, 327]; Raymond of Marseilles, *Tract. astro.* 5c–e [d'Alverny, Burnett, and Poulle 2009, 68]; Arialdus, *Cum inter omnia…* [MS Paris, Bibliothèque nationale de France, lat. 16652, f. 32r]; *Astrologie speculationis exercitium…* [Millás Vallicrosa 1942, 318]; pseudo-Māshā'-allāh, *De comp. astro.* c. 21 [Thomson 2022, 2.424–433].

[88] *L* f. 93r:

> *Ad cognoscendum quam prope sit aurora, scias quod dum nadayr ad XVIII vel, secundum quosdam, ad XVI venerit gradus ex parte almagrip…. Verbi gratia, nadayr Solis occumbente Sole est in primo almucantarat. Pone signum ad almuri. Move nadayr sursum tamdiu donec almuri attingat XVI gradus et item nota. Cum ergo per unam fixarum deprehenderis Solem tantum descendisse ut almuri XVI gradum supranotatum tangat, perfecta iam nox est et non ante. Similiter de aurora*.

of the center of a given climate.[89] The *LW* appears to be unique among the known astrolabe texts of the 11th and 12th centuries in frequently employing *altitudines* in the plural, which in all relevant instances is meant to signify a number that is physically countable on the astrolabe. This use of the term makes its first appearance in §7:

> *Nadair Solis graduque cognito, si certissime horas diei apprehendere volueris, primo altitudinem Solis per astrolapsum ita invenies: accipe astrolabium et tamdiu alhidada volves hac et illac dum radius Solis per ambo pinnarum eius cadat foramina. Quo incunctanter apprehenso numerabis a linea orientali sursum quotaque ibi interstitia apprehenderis, tot altitudines hora illa Sol habere dicetur.* [*L*, fol. 91v]
>
> Knowing the nadir and degree of the Sun, if you wish to seize the hours of the day with utmost certitude, you will first of all use the astrolabe to find the altitude of the Sun in the following way: take the astrolabe and turn the alidade this and that way until the ray of the Sun falls through the apertures of both of its vanes. Having done this, you will immediately count upward from the eastern line and the number of partitions you obtain there is the same as the number of altitudes the Sun will be said to have at this hour.

The *altitudines* mentioned in the final sentence correspond to the intervals or partitions (*interstitia*) of the circular degree scale on the astrolabe's backplate. Similar uses of "altitudines" occur in §§10–13, 29–32, 34, 43, 46. In some of these chapters [§§11–12, 30, 32], however, the *altitudines* under discussion are identified as *almucantarath altitudines* to make it clearer that what is being counted here are intervals between the almucantars inscribed on the horizon plate rather than partitions of a degree scale. According to Hermann of Reichenau and the earlier *De util. astro.*, almucantars are drawn at every 5°,[90] whereas earlier Old Corpus texts such as the *Sent. astro.* assume intervals of 6°.[91] Our text reflects this ambiguity early on in §2, where it is stated explicitly that partitions on the horizon plate are counted as either 6° or 5°.[92] The construction plan in part (iv) eventually

[89] *De util. astro.* 18.2 [Bubnov 1899, 140.11, 141.2]. The same use of "altitudo climatis" is attested in part (iv) of the *LW* [*L* f. 96r].

[90] *De util. astro.* 5.3 [Bubnov 1899, 129.13]; Hermann of Reichenau, *De mens.* cc. 2, 8 [Drecker 1931, 206, 210–211].

[91] *Sent. astro.* [Millás Vallicrosa 1931, 281.146–148]; *De divisione igitur climatum que fit per almucantarath*… [Millás Vallicrosa 1931, 321.39–49]. See also Samsó 2004a, 123 and 2020, 392.

[92] *L* f. 91r:

> *Numerato desub linea catazevel positas lineationes usque ad ipsam lineam et interstitium quodque VI vel V graduum compute. Et postquam lineationes lineam catazevel attingunt, ibi numerus deficit. Quod si finis interstitii tangit lineam catazevel in quinario vel senario finit numerus climatis. At si medium linea*

settles on 5°, in this following Hermann of Reichenau.[93] Nevertheless, the alternative convention of spacing almucantars by 6° is quietly assumed in §12, which teaches how to assess the change in solar noon altitude in the course of a month:

> *Altitudines mensis ita reperies ut quotas almucantarat altitudines principium vel finis signi ad mensem attinentis tangat invenias totque mensis dicetur altitudinum quot inter principium et finem signi altitudines deprehenderis, vel potius inter medium unius et alterius signi numeraveris. Nam quilibet mensis duobus nititur dimidiis signis, ut, verbi gratia, kal. Aprilis a XVI numerantur gradu Arietis et pridie kal. Maii quintum decimum retinet gradum Tauri, quod animadvertenti perfacile est. Est autem altitudo mensis Martii in VII climate a septima non plena ad VIII integram altitudinem. Nam XVI gradus Piscium VII non plenas, XV gradus Arietis VIII perfectas reddit altitudines.* [*L* f. 91v]
>
> You will find the altitudes of a month by finding how many altitudes among the almucantars the beginning or end of the sign that belongs to the month [in question] is able to touch. And one will say of the month that it has as many altitudes as you discern between the beginning and end of the sign or, rather, that you count between the middle of one sign and the next. For a given month corresponds to two half-signs, such that, for instance, 1 April is counted from the 16th degree of Aries and 30 April holds on to the 15th degree of Taurus, which is very easy to see. In the seventh climate, however, the altitude of the month of March is from the seventh incomplete to the eighth completed altitude. For the 16th degree of Pisces delivers seven altitudes that are not full, the 15th degree of Aries eight completed ones.

In the example provided in the final two sentences, the month of March is associated with a range of ecliptic solar longitudes from the beginning of the 16th degree of Pisces to the end of the 15th degree of Aries, which is

> *catezevel secat interstitium vel aliquam eius partem, sub quinario et unitate numerus ille finiendus constat. Verbi gratia, primum clima, quod XV continetur gradibus, tria fert interstitia, ita quod tertium in linea catazevel in medietate limitatur. Secundum XXIII graduum quatuor fulcitur interstitiis, quintum autem in medio sui lineam habet transeuntem medio interstitio quinarii tria ad XX [*L*: XXX] adicientem, dum, ut diximus, secundum clima XXIII habeat.*

As noted below [p. 32], the word "catazevel" here refers to the upper half of the central axis of the astrolabe. Of the two examples given in this passage, the first presupposes 6° per interval, but the second 5°.

[93] *L* f. 95v:

> *et quemcumque senarium secabis in VI, ita ut emiciclus ipse XXXVI referat, quarum XXXVI quamque subintellige quinque particulas claudere.*

effectively the same as 15° Aries. On a soundly constructed astrolabe with an obliquity value of 24° (as assumed in the *LW*), the solar declination values at these two moments would be in the approximate region of −5;30° and +6° (rounding to the nearest half degree).[94] On a horizon plate for the seventh climate, which corresponds to a latitude of 48°,[95] these values translate into solar meridian altitudes of 36;30° and 48°, respectively. This turns out to be consistent with the claims made in the above passage only if the almucantars are assumed as having been drawn at intervals of 6° rather than 5°. In that case, an altitude of 36;30° would encompass six whole intervals (36°), leaving the seventh interval not untouched, but incomplete (*VII non plenas*). Likewise, an altitude of 48° would encompass eight complete intervals, as stated in the text (*VIII perfectas*). Had the author of this passage thought of 5° intervals, the number of *completed* intervals should have been seven in the former case (16° Pisces) and nine in the latter (15° Aries).

4. Traces of an Arabic source

Setting aside all those chapters that have a direct or indirect precedent within the Old Corpus, or those that could have easily been composed by a discerning reader of this literature, we are left with roughly 30 chapters whose content, unless wholly original, must have been drawn from different, and presumably later, sources. In §52, for instance, the declination of the Sun's ecliptic degree (*declinatio gradus*) is used to determine local latitude during daytime, by either adding or subtracting it from the solar noon altitude on the day in question.[96] This is supplemented in the following chapter [§53] with an account of how to read this declination value off the

94 The relevant relation is $sin\delta = sin\lambda \cdot sin\varepsilon$, for the declination ($\delta$), ecliptic longitude ($\lambda$), and obliquity of the ecliptic (ε). For the obliquity of 24°, see *L* f. 95v and Hermann of Reichenau, *De mens.* c. 1 [Drecker 1931, 204–205].

95 See n 125 on p. 39 below.

96 *L* f. 94r:

> *Quovis die accipe in dorso astrolabii altitudinem Solis et declinationem gradus illius diei. Si est septemtrionalis, minue ab illa, si australis, adde ad altitudinem. Et quot supra altitudinem illam gradus usque ad meridianam lineam inveneris post additionem illam vel demptionem quam predixi inveneris [*sic*], tota est latitudo climatis tui.*

astrolabe's horizon plate.[97] Neither the term "declinatio" nor the corresponding concept play any role in the texts belonging to the Old Corpus. It is different with the astrolabe treatises written during the 12th century, several of which teach how to compute local latitude by means of the *declinatio*. Relevant authors include Raymond of Marseilles,[98] Abraham Ibn Ezra,[99] Robert of Chester,[100] and Arialdus,[101] in addition to John of Seville and Plato of Tivoli, who translated a treatise by Ibn al-Ṣaffār.[102] The same information was provided in the canons that circulated alongside the Toledan Tables, which, as seen, may have provided the *LW*'s author with the latitude of the city of Cremona.[103] It must be said, however, that a comparison of these Toledan canons and the aforementioned astrolabe texts with §§52–53 in the *LW* shows no conspicuous verbal overlap, leaving open the question of the author's immediate source of information.

Besides addressing the declination of degrees on the ecliptic, the *LW* adds a separate rule for finding the declination of an astrolabe star. Confusingly, this very brief rule, which makes up §55, refers to the relevant coordinate as the star's *latitudo*, thus masking any connection with the content of

97 *L* f. 94r:

> *Si vis declinationem cuiusque gradus per astrolabium cognoscere, vide gradus de quo queris quot gradibus a linea equinoctiali distet. Et numerus illorum graduum declinatio nominatur. Qui gradus, si versus alcitop, hoc est inter alcitop et equinoctialem lineam, erit declinatio septemtrionalis, si inter lineam equinoctialem et ansam superiorem, meridiana.*

98 Raymond of Marseilles, *Tract. astro.* 22b–c, 22n [d'Alverny, Burnett, and Poulle 2009, 96–98, 100–101].

99 Abraham Ibn Ezra, *Genera astrolabiorum…* [Millás Vallicrosa 1940, 16].

100 Robert of Chester, *De off. astro.* cc. 21–22 [MS Oxford, Bodleian Library, Canon. misc. 61, f. 17r].

101 Arialdus, *Cum inter omnia…* [MS Paris, Bibliothèque nationale de France, lat. 16652, f. 35r].

102 Ibn al-Ṣaffār, *Kitāb fī-l-ʿamal bi-l-asṭurlāb*, trans. John of Seville, cc. 22–23 [Millás Vallicrosa 1942, 273–274]; trans. Plato of Tivoli, cc. 24–25 [Lorch, Brey, Kirschner, and Schöner 1994, 156–158]. See also pseudo-Māshā'allāh, *Practica astrolabii* cc. 13, 20–21 [Thomson 2022, 4.160–161, 208–225].

103 See canons Ca48, Cb67, and Cc050 in Pedersen 2002, 234–235, 408–409, 608–611. See also *Artis cuiuslibet consummatio*, 2.20 [Victor 1979, 266–267], where the terms "remotio" and "declinatio" are used.

§53.[104] This sort of terminological split can be observed in the *Libellus de opere astrolapsus* by Adelard of Bath, who uses "latitudo" exclusively when teaching how to compute a star's declination, whereas his word for the declination of an ecliptic degree is "obliquatio".[105] The same preference for "latitudo" when writing specifically about stellar latitude is evinced in the astrolabe treatises by Robert of Chester and Arialdus.[106] Nevertheless,

[104] *L* f. 94r:

> *Latitudinem cuiuslibet stelle ita invenies. Videto quot gradibus ab equinoctium [*sic*] distet et ea est eius latitudo sicut est altitudo stelle progressio eius super numeros almucantarat*.

[105] Adelard of Bath, *De op. astrol.*:

> *Obliquationem itaque eius in ezic descriptam investigabis eamque, ssi [*sic*] schemelia fuerit, altitudini meridiane subtrahes*. [Dickey 1982, 192]
>
> ...
>
> *Si vero latitudinem investigaveris, sic invenies. Quamlibet enim stellam supra lineam meridianam pones atque ipsum almukantaraz quem tetigerit considerabis. Quantum enim inter illud almukantaraz et equinoctialem inventum fuerit, tanta stelle illius latitudo procul dubio erit. Non dissimiliter etiam cuiuslibet gradus obliquationem reperies. Ipsum enim gradum supra meridianam pones quantumque a loco sui almukantaraz usque ad equinoctialem fuerit perpendes. Tantam enim eius obliquationem intelliges*. [Dickey 1982, 211–212]

[106] Robert of Chester, *De off. astro.* c. 25 [MS Oxford, Bodleian Library, Canon. misc. 61, ff. 18v–19r]:

> *Et si cuiusvis stelle fixe latitudinem scire volueris, si stella ipsa aquilonalis fuerit altitudini eius maioris altitudinem signi Arietis quantum ad ipsam clima pertinet subtrahe reliquumque stelle eiusdem latitudinem incunctanter agnosce. Quod si ipsa stella australis extiterit, eius maior altitudo altitudini Arietis aufferatur reliquumque eius latitudo habeatur. Si vero stella ab azimut capitum eiusdem loci aquilonalis fuerit ipsaque aliqua ex illis que occasum nesciunt extiterit, eius minori altitudini altitudinem Arietis adice.... Quod si maior altitudo alicuius stelle fixe nonaginta graduum fuerit, eius latitudo latitudini eiusdem climatis erit equalis.... Per hanc igitur latitudinis stellarum inventionem etiam quot gradus ab ipso celi cardine quelibet earum distiterit non minus accipitur. Cuiusvis igitur earum latitudo, si ipsa aquilonalis fuerit, nonaginta subtrahe reliquumque quod fuerit numerum graduum distantie ipsius stelle a cardine celi demonstrat*.

Arialdus, *Cum inter omnia*... [MS Paris, Bibliothèque nationale de France, lat. 16652, f. 35v]:

> *Si per quamlibet stellam latitudinem terre tue scire volueris, nota latitudinem stelle a principio Arietis vel Libre. Secundum stelle meridiem addendo vel*

Robert at one point indicates that the alternative term "declinatio" can apply to the stars just as well as to the Sun when describing their distance from the celestial equator,[107] while Arialdus' text is explicit in treating "declinatio" and "latitudo" as synonymous.[108] It accordingly remains unclear what the parallel use of these two terms in the *LW* may imply with regard to its relationship with these other 12th-century texts.

The same problem arises again in relation to "cent" (zenith) and "assumuth" (azimuth), two Arabic-derived words that are absent from part (ii) but deployed across a total of nine chapters in part (iii). Four of these chapters contain forms of the expression "cent capitis" [§§54, 57, 62, 65], which renders the Arabic «samt ar-ra's» (direction above the head) in the form of a loanword ("cent") combined with a calque ("capitis"). In two other chapters, the text instead has "cent climatis" [§§45, 51], though the meaning is the same. The earliest Latin text to feature the former rendering of the Arabic expression is Plato of Tivoli's translation of Ibn al-Ṣaffār's treatise, which has "cenyt capitum" as well as "cenit" on its own. By contrast, John of Seville's version of the same text opts for a straightforward transliteration: "sunt alraz" or simply "zunt".[109] The first original Latin text to include "cenit capitum" appears to be the treatise by Rudolf of Bruges, which, as was noted above, shares with the *LW* its description of the alidade as a *linea*.[110]

> *minuendo terre tue latitudinem reperies. Verbi gratia, sit stella que habet latitudinem a medio mundi X graduum; ergo medium mundi facit latitudinem [*sic for *altitudinem] LXXX, quare illi quibus ascendit per XC gradus distant a medio mundi X gradibus.*

107 Robert of Chester, *De off. astro.* c. 21 [MS Oxford, Bodleian Library, Canon. misc. 61, f. 17r]:

> *Solis autem et stellarum fixarum a circulo equinoctiali in aquilonem et austrum declinatio per astrolabium hac ratione colligitur.*

108 Arialdus, *Cum inter omnia…* [MS Paris, Bibliothèque nationale de France, lat. 16652, f. 35r]:

> *Si vero in aliis locis fuerit [*scil. *Sol] tunc minue latitudinem eorum locorum, sive declinationem ab Ariete vel Libra, vel adde altitudini quam habuisti et habebis altitudinem equinoctii per quam latitudinem terre tue colliges.*

109 Ibn al-Ṣaffār, *Kitāb fī-l-ʿamal bi-l-asṭurlāb*, trans. John of Seville, c. 1, 31–32, 34 [Millás Vallicrosa 1942, 263, 278–279, 281]; trans. Plato of Tivoli, c. 1, 29, 33–34 [Lorch, Brey, Kirschner, and Schöner 1994, 140, 161–162, 165]. See also pseudo-Māshāʾallāh, *De comp. astro.*, prol. cc. 13–15, 19–21 [Thomson 2022, 2.6–9, 280–281, 288–289, 314–315, 320–321, 324–327, 314–317, 334–335, 396–397, 402–403, 410–411, 414–415, 424–425]; and his *Pract. astro.*, prol. cc. 21, 23 [Thomson 2022, 4.18–19, 216–217, 236–237, 240–241]. For other attestations and remarks on the origin of this term, see Kunitzsch 1982, 546–549.

110 Rudolf of Bruges, *Cum celestium…* c. 12 [Lorch 1999, 72].

The other Arabic word, "assumuth" (from "as-sumūt", the directions), makes its appearances in §§41, 58, and 60.[111] Once again, the term in question can be found in the Ibn al-Ṣaffār translations by John ("azimut", "azumut", "aszimut", also "zunt") and Plato ("azimut", "azenit").[112] Rudolf of Bruges was likewise familiar with it, although he mistakenly treated "cenit capitum" as one of its synonyms.[113] Among the other 12th-century Latin astrolabe texts that early on deployed some variant of "azimuth" are a construction treatise attributed to John of Seville,[114] the *Tract. astro*. of Raymond of Marseilles,[115] and the slightly later texts by Adelard of Bath ("alcemut", "elcemut"), Abraham Ibn Ezra ("acemuth"), and Robert of Chester.[116]

As in the case of "declinatio", a comparison of this literature with the *LW* fails to reveal similarities that would be substantial enough to indicate a direct relationship, much in contrast to the many evident borrowings from Old Corpus texts such as *De util. astro*. and Hermann of Reichenau's *De mens. astro*. For an example of the degree to which some of the chapters in part (iii) of the *LW* stand apart from the known astrolabe literature of this period, we can turn to §41:

> *Ut scias que civitas tue civitati dextra vel sinistra iaceat cognito utriusque latitudine, si illius civitatis latitudo plurium fuerit graduum quam tue civitatis gradus sint, erit tibi sinistra. Si pauciores habuerit gradus illa civitas quam tua habuerit*

[111] On the origin of this term and its attestations in Latin astrolabe literature, see Kunitzsch 1982, 549–553.

[112] Ibn al-Ṣaffār, *Kitāb fī-l-ʿamal bi-l-asṭurlāb*, trans. John of Seville, cc. 1, 19, 21, 27, 31–32 [Millás Vallicrosa 1942, 263, 271–272, 276, 279]; trans. Plato of Tivoli, cc. 1, 20, 23, 29, 33–34 [Lorch, Brey, Kirschner, and Schöner 1994, 140, 153–154, 156, 161, 165]. See also pseudo-Māshā'allāh, *De comp. astro*. cc. 12, 14–16, 19–20 [Thomson 2022, 2.260–261, 298–301, 320–321, 332–335, 340–341, 396–405, 410–417] and his *Pract. astro*., prol. cc. 17–19 [Thomson 2022, 4.18–19, 182–187, 194–195, 198–199].

[113] Rudolf of Bruges, *Cum celestium*… c. 12 [Lorch 1999, 72–73].

[114] John of Seville, *Dixit Johannes*… [Millás Vallicrosa 1942, 326]. See also the text beginning *Astrolog. spec. exer*.… [Millás Vallicrosa 1942, 317–318].

[115] Raymond of Marseilles, *Tract. astro*. 4f–h, 4l, 5b [d'Alverny, Burnett, and Poulle 2009, 64, 66, 68].

[116] Adelard of Bath, *De op. astrol*. [Dickey 1982, 198, 208, 212]; Abraham Ibn Ezra, *Genera astrolabiorum*… [Millás Vallicrosa 1940, 11]; Robert of Chester, *De off. astro*. cc. 20, 24–25, 26, 29–30 [MS Oxford, Bodleian Library, Canon. misc. 61, ff. 16v–17r, 18r–19r, 20v]. See also Arialdus, *Cum inter omnia*… [MS Paris, Bibliothèque nationale de France, lat. 16652, f. 30r].

> *gradus, erit tibi dextra. Si non plures habuerit illa quam tua, erit assumuth a tua civitate ad illam*. [*L* f. 93r]
>
> In order for you to know which city lies to the right or left of your own, given knowledge of either [city's] latitude, [follow this rule]: if the latitude of this city contains more degrees than your city, it will be to your left. If this city has fewer degrees than your own, it will be to your right. If it does not have more than yours, there will be an azimuth between your city and this one.

The problem discussed here is rather trivial, namely, the implication of the latitudes of two different cities for their relative positions. A feature that makes this discussion unusual, however, is the use of the adjectives "left" (sinistra) and "right" (dextra) for what would ordinarily be thought of as "north" and "south". We are told that if the latitude of another city is greater than one's own, it is located to the left, while cities with a smaller latitude are located to the right. This use of "left" and "right" can also be discerned in the following passage from part (ii), which describes the two halves of the vertical (i.e., north to south) line on the astrolabe's horizon plate:

> *Et ea quidem linea que <ab> alcitop…ex parte dorsi per almucantarat versus dextram tuam transit in eundem alcitop, dum astrolabium sic tenes quod ansa eius est in dextra tua, linea dicitur dextra vel meridiana, aut certe secundum Arabes linea cateizesel. Porro ea que ab alcitop versus sinistram tuam per almucantarat in eundem alcitop venit linea sinistra vel linea anguli terre aut certe septemtrionalis appellatur*. [*L* f. 90v]
>
> And the line that passes from the *alcitop* on the back plate through the almucantars toward your right hand [and] back to the same *alcitop*, while you hold the astrolabe in such a way that its handle is in your right hand, is called the "right" or "southern" line, or *cateizesel* according to the Arabs. Moreover, the line that [starts at the] *alcitop* and arrives back at it [by going] toward your left through the almucantars is called the "left one" or the "line of the angle of the Earth" or, at any rate, "the northern one".

Both of the Arabic loan words encountered in this passage were transmitted as part of the Old Corpus [Kunitzsch 1982, 524–525, 545–546]. One is "alcitop" (from « al-quṭb », axis or pole), which refers to the central axis of the astrolabe. The other is "cateizesel", which elsewhere in our text [§§2, 5] is rendered somewhat more adequately as "catazevel" or "catezevel". It derives from « ḫaṭṭ al-zawāl » (line of the disappearance [of the shadow], i.e., the line representing noon) and normally designates the lower half of the vertical line (i.e., the half located below the horizon). In the above passage, this name is instead applied to the upper half representing the southern direction. If the astrolabe is held horizontally by its suspension in one's right hand, this half of the line will be closer to the right, while the opposite half of the same line will be toward the left. This principle can be applied to the zenith of a particular latitude, which will be farther right the farther south it appears on the horizon plate. While the use of "dextra" and "sinistra" in §41 can thus be explained as evoking the physical dimensions of the astrolabe, it is unlikely to be a pure coincidence that it closely mirrors the Arabic language, where "shimāl" and "yamīn" have dual meanings of "left/north" and "right/south".

The other aspect of §41 that requires discussion is the final sentence, which seems to state that there will be an *assumuth* between two cities that occupy the same latitude. This much seems clear from the context of the preceding sentences, which dictates that the condition expressed in the final sentence as "Si non plures habuerit" (If it does not have more) must be interpreted as also including "Si non pauciores habuerit" (If it does not have fewer). While it seems evident that the word "assumuth" is here related to the east-west direction, which is the only possible directional difference for two cities with identical latitudes, the author nowhere defines or explains the term in question, much in contrast to the Arabic vocabulary introduced in part (ii). Some clarification is provided in §58, which deals with the use of the noon shadow to find the four cardinal directions. The chapter describes a wooden instrument based on a shadow stick and in this context mentions two different kinds of azimuth, of which one represents due east-west (*assumuth tui orientis vel occidentis*) and the other north-south (*assumuth meridiei tui et septemtrionalis*).[117] We encounter the term a final time in §60, which offers one of the most cryptic passages in the entire text:

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[117] *L* f. 94r:

> *Sole posito in puncto meridiei erige ortogonium contra Solem quod rectum habeat angulum et tamdiu move dum angulus rectus in instrumento rectus quoque sit in umbra. Tunc per astrolabium caput et finem prendens umbre sub uno gradu, scito in ipso gradu assumuth civitatis tue ad aliam eiusdem latitudinis a medio mundi. Quod ipsum dicetur assumuth tui orientis vel occidentis. Erige lignum ortogonaliter et Solem ita formatum—L—in medii diei puncto, ita quod umbra cateti cadat super umbram basis. Et secundum gradum basis habes assumuth meridiei tui et septemtrionalis. Si qua igitur civitas est eiusdem longitudinis cum tua civitate, sed minoris latitudinis, versus ad meridiem cum astrolabio secundum gradum predicti ortogonii habes assumuth illius civitatis. Quod si aliqua eiusdem longitudinis, sed maioris latitudinis, versus ad septemtrionem cum predicto gradu assumuth ipsius invenies.*

> *Prensa altitudine Benenaz summa, vide civitatem cuius assumuth queris, si est latior civitate tua et longior, quot gradus a meridiana distet. Et cum Benenaz descendendo ad totidem venerit gradus, prende ipsum et ecce assumuth illius civitatis. Quod si est latior [*sic*] civitate tua, sed longior [*sic*], vide quot horis a meridiana distet—quot, inquam, horis vel partibus hore. Et ubi numerus desierit apprehensa altitudine Solis, hec assumuth illius civitatis. Quod si civitas aliqua brevior fuerit tua civitate, sed latior, numerum graduum ipsius a meridiana et descensu Benenaz habebis assumuth. Quod si brevior fuerit et angustior tua civitate, per Solem habebis assumuth ultra*. [*L* f. 94v]
>
> Having found the highest altitude of Benetnasch, look up how many degrees the city whose azimuth you seek is away from the meridian, if it is wider and longer than your city. And when Benetnasch in descending arrives at this number of degrees, capture it and there is the azimuth of this city. If it is wider [!] than your city, but longer [!], look up how many hours it is away from the meridian—how many hours, that is, or parts of the hour. And where the number stops, having seized the altitude of the Sun, this is the azimuth of this city. But if some city is shorter than your city, but wider, [take] its number of degrees from the meridian and through the descent of Benetnasch you will have the azimuth. But if it is shorter and narrower than your city, you will obtain the azimuth through the Sun.

The overall purpose of this passage seems clear enough, namely, to explain how one can find the direction (*assumuth*) of a particular city with respect to one's own location. Rules to this effect appear in the translations of Ibn al-Ṣaffār's treatise as well as in the *Liber de officio astrolabii* written by Robert of Chester,[118] but these descriptions bear no resemblance to the present chapter. What they teach is how to use the astrolabe to compute the azimuth angle of a place from its known latitude and longitude. By contrast, §60 in the *LW* assumes that this angle is already known. To find the corresponding direction in the heavens, the author recommends tracking the altitude of either the Sun or the star Benetnasch (Arabic: daughters of the bier), which is also known as Alkaid (η Ursae Majoris). Once the relevant body has reached an altitude that coincides with the right azimuth angle on the horizon plate, its visible position can be used to pinpoint the direction of the city.

[118] Ibn al-Ṣaffār, *Kitāb fī-l-ʿamal bi-l-asṭurlāb*, trans. John of Seville, c. 27 [Millás Vallicrosa 1942, 276]; trans. Plato of Tivoli, c. 29 [Lorch, Brey, Kirschner, and Schöner 1994, 161–162]; Robert of Chester, *De off. astro*. c. 26 [MS Oxford, Bodleian Library, Canon. misc. 61, f.19r].

Whether one or the other celestial body is employed for this purpose depends on the latitude of the city whose direction is sought. This much is implicit in the order in which the text mentions the four possible positions a city may occupy relative to one's place of observation. These positions are described using two contrasting pairs of adjectives, "latior/angustior" (wider/narrower) and "longior/brevior" (longer/shorter). It stands to reason that these must refer to the greater or smaller geographic latitude and longitude of a city. The possible positions that arise from these options are the following:

(i) "latior" (greater latitude) and "longior" (greater longitude)
(ii) "angustior" (smaller latitude) and "longior" (greater longitude)
(iii) "latior" (greater latitude) and "brevior" (smaller longitude)
(iv) "angustior" (smaller latitude) and "brevior" (smaller longitude)

Rather than listing these four possibilities in this particular order, the text cited above omits "angustior/longior" in position (ii) and instead repeats the first pairing, "latior/longior". Once we correct this to "angustior/longior", the text becomes consistent in stating that cities farther south (*angustior*) than the observer are located using the altitude of the Sun, while those farther north (*latior*) must be found *via* the altitude of Benetnasch. As we shall see, this star is also mentioned in several other chapters of the *LW*, some of which assume that it is on the parallel 36° below the north celestial pole [see p. 38 below]. Its mention in §60, and similarly in §47 (which teaches how to locate the meridian), does not depend on this specific position. Rather, the author appears to have selected it from among the fixed stars because, at his own latitude, it fulfilled the dual condition of being circumpolar (and, hence, ever visible) and having its upper and lower culminations in the north (i.e., north of the zenith).[119] As a consequence, Benetnasch possessed the positional features needed to mark, by virtue of its altitude, the direction of cities located farther north than the observer.

It bears repeating that the very simple and concise instructions given in §60 rest on the assumption that the astrolabe user has prior knowledge of the azimuth angle of the city in question. In the passage at hand, the

[119] The declination of Benetnasch in 1175 was ≈ +53;33°, making it circumpolar at latitudes above 36;27° and always culminating in the north at latitudes below 53;33°. An additional factor in selecting Benetnasch may have been that it is the first star mentioned in the chapter on astrolabe stars in *De util. astro.* 17 [Bubnov 1899, 136. 20]. On this chapter, see Kunitzsch 2000b. Benetnasch is also mentioned among the circumpolar stars in Raymond of Marseilles, *Tract. astro.* 22p [d'Alverny, Burnett, and Poulle 2009, 100].

term "assumuth" denotes a physical direction in the sky as opposed to a numerical parameter. The azimuth angle itself is instead referred to quite simply as the number of degrees from the meridian line (*numerus graduum a meridiana*). At least this is so in the two instances where the city whose direction is being sought is located farther north (*latior*). In the second of the four scenarios listed above, the text instead mentions hours as well as their parts (*vide quot horis a meridiana distet*). It seems difficult to discern a reason behind this variation.

One important point our text passes over in complete silence is that the altitude at which the Sun or Benetnasch will point to the correct azimuth angle can be found on the astrolabe's horizon plate only if it is inscribed with azimuth curves in addition to almucantars. As noted above [p. 13], such curves are never mentioned in texts belonging to the Old Corpus. It is only in the 12th century that they begin to appear in descriptions of how to construct an astrolabe.[120] The operation described in §60 is therefore rather alien to the astrolabe design described in parts (ii) and (iv) of the *LW*, which once again raises questions about the sources that underlie those passages of part (iii) that cannot be traced back to the Old Corpus.

One hypothesis that may explain some of the difficulties in the wording of §60 as well as the unexpected presence of the term "assumuth" is that the author relied on a (possibly defective) translation of an as-yet unidentified Arabic text. Further reasons to take this hypothesis seriously are furnished by the chapter that immediately follows [§61]. Its subject is how to find the direction of something here labeled the "naturalis meridies" or "natural noon":

> *Ad inveniendam naturalem meridiem, scito quantum tua civitas distat a meridiana linea. Quot ergo horis destiterit, tot horis vel partibus hore ante tuum meridiem ille erit naturalis meridies, si tua civitas est in occidentali parte; vel tot horis precedit tuus meridies naturalem meridiem, si fuerit tua civitas ex parte orientali, si Deus voluerit.* [*L* f. 94v]
>
> To find the natural noon, know your city's distance from the meridian line. The hours of this distance are the same number as the hours or parts of the hour by which this natural noon will be ahead of your own noon, if your city is in the western part; or by which your own noon precedes the natural noon, if your city lies in the eastern part, God willing.

Once again, we are confronted with some rather idiosyncratic uses of vocabulary. The *naturalis meridies* mentioned in this passage clearly must signify something other than the observer's meridian, since it is assumed that the

[120] For relevant attestations, see nn 111–116 above.

city at which one is located can be at a distance from this "natural noon". Confusingly, we are told that this distance is found via the city's distance from the meridian line (*linea meridiana*), which would seem to suggest that "naturalis meridies" and "meridiana linea" are here used as synonyms. The distance in question is measured in hours and parts of the hour, which were mentioned in §60. We are told that if the city is located "in the western part" (*in occidentali parte*), the distance from the *meridiana linea* will reveal how many hours the *naturalis meridies* is ahead of the city's own meridian. Conversely, if the city is located in the east, its position precedes that of the *naturalis meridies* by the relevant number of hours.

It would appear that the only way to make sense of these remarks is to read "naturalis meridies" and "linea meridiana" as denoting some prime meridian relative to which the geographic longitude of cities is measured. Since it is assumed that places can lie on either side of this prime meridian (in the eastern or western part of the world), one can rule out that the author had in mind a far-western zero meridian such as the "meridian of water" known from Andalusian astronomy.[121] Rather, the description presupposes a prime meridian that marks the "middle of the world", as is the case with the meridian through Arin (Ujjain in India), which was introduced into al-Andalus, and subsequently also into the Latin world, through the astronomical tables of al-Khwārizmī.[122]

The question remains of why the author chose to refer to this meridian with a label as ambiguous and misleading as the "true noon" (*naturalis meridies*). Could it be that some of the odder terminological choices that are observable in parts of the *LW* are the result of translating literally a text written in another language? If the chapters discussed above were drawn from a translation of an unknown Arabic source, this might explain the author's familiarity with the terms "cent" and "assumuth". Moreover, it would account for the way §61 closes with "si Deus voluerit" (God willing), which is here added to the unlikely scenario of a reader living east of the

[121] On this meridian, see Comes 1992–1994; Samsó 2020, 703–708.

[122] See *Ezich Elkaurezmi*, trans. Adelard of Bath [Suter 1914, 1]. Examples of its presence in 12th-century Latin astronomy include the Toledan canons Ca82, 90; Cb133 [Pedersen 2002, 250–251, 254–255, 430–431]; Adelard of Bath, *De op. astrol.* [Dickey 1982, 163–168, 193–196]; Raymond of Marseilles, *Curs. plan.* 1.62b–63a, 82b, 2.1a, 1d, 3a [d'Alverny, Burnett, and Poulle 2009, 172, 184, 200, 204]. Further references are provided in Sela, Steel, Nothaft, Juste, and Burnett 2020, 209–210 n78.

prime meridian. These words are easily recognizable as a Latin rendering of «inshallah», a phrase commonly found in Arabic texts on astronomical instruments and tables. It concludes, for instance, multiple chapters in John of Seville's translation of Ibn al-Ṣaffār's treatise on astrolabe use.[123] There seem to be good reasons, then, to count a translated Arabic text among the sources that underpin the *LW*'s part (iii).

5. The declination of Benetnasch

Benetnasch, the star that features so prominently in one of the chapters discussed in the preceding section [§60], also plays a role in seven other chapters of the *LW*'s "use" part [§§32, 47, 62–65, 67]. In four of these [§§62–63, 65, 67], the star is selected for a very specific reason, namely, its assumed position on the celestial parallel that divides the northern temperate and frigid zones—36° from the north celestial pole [see pp. 20–22 above]. The following passage from §62 relies on this position while also presupposing that the star culminates in the north:

> *A summa quippe altitudine Benenaz XXX numeratis gradibus per cent capitis quicquid per alhidada appareret stella sive pars firmamenti esset certe tropicus estivalis, paralellus limitans perustam a nostra temperata.... Inde retrosum per XXIIII gradus deposita alhidada per foramina pinnularum prospiceret paralellum peruste medium. Ab ipsis nichilominus XXIIII gradibus aliis XXIIII computatis gradibus videret tropicum hiemalem paralellum. Porro illum paralellum, qui australem habitabilem a frigida inhabitabili seiungit, videre non posset nisi in fine <IIII>* [124] *climatis constitutus et infra [*L*: intra] versus meridiem.* [*L* f. 94v]
>
> Having counted 30° from the highest altitude of Benetnasch [*scil.* from the north] across the zenith, whichever star or part of the firmament would appear through the alidade would certainly be the summer tropic, [which is] the parallel separating the torrid from our temperate zone.... From there, having pulled the alidade back by 24°, [the observer] would look out for the middle parallel of the torrid zone [*scil.* the equator]. Having counted another 24° from these 24°, he would see the winter tropic. The only way he could see this parallel, which separates the southern habitable from the [southern] frigid zone, is if he is stationed at the end of the fourth climate and farther toward the south.

The final sentence addresses the visibility of the southern counterpart of the parallel between the northern temperate and frigid zones, which is assumed to disappear from view at a northern latitude of 36°. According to a tradition transmitted via Old Corpus texts such as *De util. astro.*, this latitude is closely

[123] Such is the case in cc. 16–18, 23–24, 28, 39–40 of this translation. See Millás Vallicrosa 1942, 271, 274–275, 277, 283–284. The phrase is also used in Raymond of Marseilles, *Tract. astro.* 16b, 23b [d'Alverny, Burnett, and Poulle 2009, 92, 102].

[124] The number missing here is supplied in *M* f. 24v.

associated with the fourth climate. It seems manifest that the author of §62 relied on this convention but mistakenly assumed that the latitudes assigned to the climates refer to their northernmost extent rather than their center. This explains his reference to the end (*in fine*) of the relevant climate in the above passage. In fact, the same misconception emerges from §2, where the author states that the first climate contains 15°.[125]

To return to Benetnasch, the $30° + 24°$ that in the above passage are reckoned from its altitude at upper culmination to the equator clearly imply that the star and its associated parallel have a declination of +54°.[126] Modern calculation shows that this was very close to Benetnasch's actual declination in the years around 1090. By 1175, which may be deemed closer to the composition of the *LW*, it had diminished to ≈ 53;33°, which is still within half a degree of the value implied in our text. The accuracy of this coordinate in the *LW* seems noteworthy considering that none of the known Old Corpus texts record declination values. While Benetnasch is included in the aforementioned list of 27 astrolabe stars, the two coordinates actually provided in this list are the mediation, which is sometimes confusingly labeled "latitudo", and another positional value termed the "altitudo". The latter referred to what John North has dubbed the "marginal longitude"—an astrolabe-specific value used to fix a star's position on the rete with the help of a ruler.[127]

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125 *L* f. 91r: "Primum clima, quod XV continet gradibus". See also §67 quoted in n126 below. The latitudes the *LW* assigns to the seven climates are 15°, 23°, 30°, 36°, 41°, 45°, and 48° [§1 and *L* f. 95v]. These are the specific values mentioned in *Regule de quarta parte astrolabii* [Millás Vallicrosa 1931, 307.52–58]; *De util. astro.* 18.2 [Bubnov 1899, 141.2–7]; Hermann of Reichenau, *De mens.* c. 2 [Drecker 1931, 205]. On the background, see Honigmann 1929; Borrelli 2008, 41–42, 180–181, 206–210.

126 The same value is implicit in §67, for which see *L* f. 95r:

> *Cum autem apprehensa summitate Benenaz quot gradus a linea meridiana usque ad gradum altitudinis inveneris, tot inter te et principium frigide esse non dubium sit. Tamen et ex hoc perpendas, licet quod queque sexagena VI continent gradus. A medio autem mundi, hoc est ab loco altitudinis Solis in capite Arietis vel Libre, XC sunt gradus usque ad polum, quorum graduum primum clima XV et cetera per ordinem queque ponunt. Quotcumque graduum fuerit clima tuum, vide quid restet usque ad XC et tot sunt gradus inter te et polum. Est autem latitudo frigide septemtrionalis XXXVI gradus, quos de priori restantia aufer. Et si quid plus est, inter te et principium frigide numerus est graduum.*

127 North 1976, 3.159–161. See also the discussions in Poulle 1955, 124–125; Viladrich

Following Julio Samsó [2000, 510 and 2020, 384], its relation to a given star's declination may be expressed as follows:

$$Rcos\beta = tan\left(\frac{90^\circ - \delta}{2}\right), \tag{1}$$

where β is the *altitudo*, δ the declination, and *R* the radius of the circle of Capricorn in relation to the equator. Using, as did Old Corpus astrolabe designs, an obliquity of 24°, the value of *R* will be

$$R = tan\left(\frac{90^\circ + 24^\circ}{2}\right) = 1.5399. \tag{2}$$

Now, the *altitudo* assigned to Benetnasch in the aforementioned list is normally 74°, as is indeed the case with the recension attached to the *LW* in *L* [fol. 97v].[128] Assuming that β = 74°, the declination (δ) implied by equation (1) will be approximately 44°—well below the declination value implied by our text. It seems doubtful, therefore, that the position espoused in the *LW*, according to which Benetnasch lies 36° below the celestial north pole, could have been derived merely from studying an astrolabe constructed according to specifications drawn from the Old Corpus.

Could it be the case, then, that the placement of Benetnasch on the northern parallel was a consequence of the author's practical experience? One reason this scenario is worth considering is the existence of the previously mentioned *sphaera* of St Emmeram, whose potential observational uses have been studied by Michael Schonhardt. He convincingly shows that one of the monument's practical purposes was to track and identify stars on the basis of their proximity to the five parallel circles inscribed on its surface. This could be done by orienting the *sphaera* toward due south and using sighting pegs to mark the positions of the different parallels in the sky [Schonhardt 2022, 237–240]. The example of the *sphaera* thus indicates that an interest in the positions of stars relative to the celestial equator and the know-how required to establish these positions existed in a southeastern German monastic milieu in the second half of the 11th century.[129] If the *LW*

and Martí 1981, 94–96; Bergmann 1985, 46–55; Samsó 2000, 508–512 and 2020, 382–385.

128 See the renditions of this list in Kunitzsch 1966, 28, as well as Millás Vallicrosa 1931, 301 (*De mens.*); Drecker 1931, 209 (Hermann of Reichenau); Bergmann 1980, 82; Burnett 1998, 350 (Ascelinus of Augsburg).

129 It should be mentioned in this context that the diagram of celestial parallels on the *sphaera* is drawn for a latitude of 48°, which is about 1° below the correct value for Regensburg (49;1°). Assuming no other sources of error, this deviation of the

originated in the same context (albeit a century later), this may add plausibility to the idea that the information about the star Benetnasch presented in this text rested on some observational basis.

An alternative possibility, according to which the references to Benetnasch entered the *LW via* a source originally composed much farther south, is raised by the content of §32, which reminds the reader that the accuracy of a measurement or, conversely, the reliability of an astrolabe can be tested by comparing the measured maximum altitude of an astrolabe star with the altitude reached by the relevant star pointer on the horizon plate. By way of example, the text here notes the maximum altitudes that Alhabor (i.e., Sirius or α Canis Majoris) as well as Benetnasch attain "in our climate" (*in nostro climate*). Of Alhabor, it is said that it never exceeds six *altitudines* among the almucantars, whereas Benetnasch is claimed even to ascend beyond 12 *altitudines*.[130] It may seem sensible to approach these remarks in the light of §12 [discussed on pp. 26–27 above], where the climate of reference is the seventh, with an associated latitude of 48°, while the *altitudines* evidently refer to 6° intervals between the almucantars on the horizon plate. If the latter conditions also applied in the case of §32, it would follow that the author placed the upper culmination of Alhabor at $\leq 36°$ and that of Benetnasch at $> 72°$.

The information given for Benetnasch may be too vague to draw firm conclusions. Nevertheless, if the declination value implicit in the aforementioned star list ($\approx 44°$) were used to derive the culmination altitude of this star at a geographic latitude of 48°, the result would be 86°, which exceeds the sum of 14 6° intervals.[131] Using the value of $\delta = 54°$ implicit in the *LW* reduces

inscribed from the true pole by 1° would have had the effect of lowering the observable declination of Benetnasch by the same amount. Given the low precision of the instrument in question, which was graduated according to 6° intervals (Hyginus' *partes*), this can be considered a negligible error.

130 *L* ff. 92v–93r:

> *Si stellam in pluribus per alhidada foraminibus vel paucioribus quam ipsa in almucantarath ascendat invenisti, scito quod vel corruptum constat astrolabium vel tu male eam pervidisti. Verbi gratia, est stella Alhabor, hoc est lingua, que numquam ad plures in nostro climate ascendit altitudines nisi ad VI, utpote valde iacens ad austrum. Est Benenaz, que* [L: *qua*] *etiam ultra XII levari certum est almucantarath altitudines.*

131 The relevant relation is $\alpha = 90° - \varphi + \delta$ for the altitude at upper culmination (α), geographic latitude (φ), and declination (δ).

this result only slightly to 84°. Neither altitude is a particularly close match with the claim in §32 that Benetnasch rises beyond 12 6° intervals (*ultra XII levari certum est*), which would rather seem to suggest a value between 72° and 78°.

Alhabor's actual declination in 1175 was −15;53°, which at 48° geographic latitude would translate into an approximate culmination altitude of 26°. According to the aforementioned list of 27 stars—in the specific recension transmitted by Hermann of Reichenau and attested in manuscript *L*—Alhabor has an *altitudo* of β = 36°,[132] which equates to an approximate declination of 12½° according to equation 1 [p. 40 above]. An astrolabe constructed on the basis of this star table and equipped with a horizon plate for the seventh climate (48°) would accordingly have shown Alhabor as reaching a maximum altitude of around 29½°. Since the author in §32 speaks of an upper limit of six almucantars (*numquam ad plures in nostro climate ascendit altitudines nisi ad VI*), this means either that the *altitudes* in this chapter refer to 5° intervals or that the climate of reference is considerably farther south than 48°.

It is possible to obtain a more satisfactory solution by placing the author of these lines in the fifth climate, which the *LW* and other Old Corpus sources associated with a geographic latitude of 41° [see n125 above]. On a horizon plate for this latitude, an astrolabe whose star pointers conform to the standard list of coordinates would allow Alhabor to reach a culmination altitude of 36½°, in good agreement with the 6 × 6° = 36° alluded to in §32. For Benetnasch, the alternatives are 87°, if the star is placed according to the *altitudo* of β = 74°, or 77°, if the declination is assumed to be +54° (as elsewhere in the *LW*). The latter result seems to agree best with the wording in §32 (*ultra XII levari certum est*), which suggests a culmination altitude in the interval between the 12th (72°) and 13th (78°) almucantar.

It would appear, therefore, that the *LW* drew its information about the maximum altitudes of the two stars Alhabor and Benetnasch from different sources. Alhabor's value was plausibly read off an astrolabe that was constructed in line with Old Corpus specifications, which included faulty positional data for certain stars. This was not the case for Benetnasch, for which the *LW* consistently assumes a much better declination value than what could be found through the available star lists. It is not implausible that this better declination value had in fact been observed, whether by

[132] See *L* f. 97v and Drecker 1931, 209.

the author of the *LW* himself or by one of his predecessors. The *sphaera* of St Emmeram, which operated with the same 6° intervals as implicitly used in our text, gives us a template of how such an observation could have been carried out in the monastic milieu from which the *LW* presumably sprang. However, the probable use of the fifth climate as “our climate” in §32 points to an origin much farther south—one consistent with the Catalonian background of the earliest entries in the Old Corpus.[133]

6. Astronomical oddities

If more evidence of the *LW*’s 12th-century origin were required, it could be gleaned from some chapters in part (iii) dealing with how to find the ecliptic longitudes of the Moon and planets. This is another topic that is completely absent from the texts of the Old Corpus, which mainly present the astrolabe as a time-measuring device. As with other applications of the astrolabe, the first Latin source to discuss its potential use in locating the Moon and planets on the ecliptic was Ibn al-Ṣaffār’s treatise, as translated by John of Seville and Plato of Seville. Ibn al-Ṣaffār describes the following four techniques in the course of a single chapter:

(i) finding the longitude of the Moon during the night by reference to the position of a known star;
(ii) finding the longitude of the Moon during daytime by reference to the position of the Sun;
(iii) finding the longitude of a planet by reference to the position of a known star; and
(iv) making measurements over successive nights to determine whether a planet’s motion is direct, stationary, or retrograde.[134]

In the *LW*, the first three of these topics are discussed across three different chapters, which are placed at a significant remove from each other. The final chapter of part (iii), §68, gives a concise explanation of how to locate planets,[135] while two earlier chapters, §§36 and 44, do the same for the Moon

[133] On the use of the fifth climate and reference latitudes in the area of 41°–42° in Old Corpus texts, see Samsó 2004a, 123–124.

[134] Ibn al-Ṣaffār, *Kitāb fī-l-ʿamal bi-l-asṭurlāb* c. 39; trans. John of Seville, c. 37 [Millás Vallicrosa 1942, 282]; trans. Plato of Tivoli, c. 39 [Lorch, Brey, Kirschner, and Schöner 1994, 171–172]. See also pseudo-Māshāʾallāh, *Pract. astro.* cc. 31–32, 34, 36 [Thomson 2022, 4.296–315, 324–329, 334–341].

[135] *L* f. 95r:

> *In quo gradu sit quisque planeta sicut de Luna deprehendes, ut, verbi gratia, quia Lucifer vel Hesperus Venus est, unam de infixis perpende et muta super altitudinem suam et ipsa hora altitudinem Veneris inventam considera quis signi*

during day- and nighttime.[136]

The fourth subject, which is that of recognizing stationary *vs* retrograde motion, is not mentioned directly in our text, although the concept of observing a planet's change of position over successive days does appear in §34.[137] Here the issue at hand is how to tell a fixed star apart from one of the five planets, a topic that is only rarely addressed in 12th-century astrolabe texts.[138] The relevant chapter in the *LW* specifies rates of motion for each

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> *gradus attingat. Ibi est ipsa ne dubites. Sic de omnibus.*

For other presentations of this technique, see Raymond of Marseilles, *Tract. astro.* 16a–b [d'Alverny, Burnett, and Poulle 2009, 92]; Adelard of Bath, *De op. astrol.* [Dickey 1982, 216]; Robert of Chester, *De off. astro.* c. 15 [MS Oxford, Bodleian Library, Canon. misc. 61, f. 15v]; Arialdus, *Cum inter omnia…* [MS Paris, Bibliothèque nationale de France, lat. 16652, f. 36v]; pseudo-Hermes, *De sex rerum principiis* 30 [Lucentini and Delp 2006, 210]; *Artis cuiuslibet consummatio*, 2.22 [Victor 1979, 270].

136 *L* f. 93r:

> *Ut scias in quo signi gradu sit Luna ipsa cum Sole superius posita sic facito. Solis apprehensa altitudine Lunam similiter cape et Sole posito in sua altitudine vide quis gradus eam tangat altitudinem in qua Lunam cepisti et ibi est Luna.*

L f. 93v:

> *Gradum Lune in nocte sic invenis ut stella aliqua astrolabii locata super inventam altitudem videas, altitudo pro Luna inventa, in quo iaceat gradu et ipse dicitur gradus Lune et ibi indubitanter est Luna.*

137 *L* f. 93r:

> *Ut cognoscas sitne planeta necne stella quam cernis, primum scias quamdiu planeta aliquis in uno gradu signi stare debeat. Verbi gratia, Saturnus mensem unum in unoquoque signi gradu commoratur. Iovis XII dies. Mars duos dies et semis. Venus et Mercurius parum minus una die et nocte. Proponamus ergo unam quamvis quam ignoremus de qua, ut certum quod iudicare possimus, sic inveniamus. Stellam quamvis in astrolabio notemus in quotquot volumus altitudinibus. Aliamque in astrolabio unam prefata in tot posita altitudinibus videamus quantum et ipsa ascendit eamque de qua dubitamus ipsa vice notemus quantum ascendens in quota iacuerit altitudine. Post duos dies et dimidium locata prima illa stella in sua altitudine alteraque similiter inventa ut ante, si eam de qua dubitas uno gradu plus quam prius inveneris, verbi gratia, Mars est.*

138 The only parallel known to me is a brief text in MS Avranches, Bibliothèque municipale, 235, f. 30r (s. XII^{med}):

> *Si per astrolapsum planetas cognoscere cupis, apprehende altitudinem cuiuslibet que sit in ipso et firmiter ipsam altitudinem tene. Tunc iterum apprehende stelle*

for the five planets by noting the time they take to traverse a complete degree. In the case of Saturn, Jupiter, Venus, and Mercury, this information conforms to what could be found in the classical Roman sources available in Latin Europe before 1100, which included Hyginus, Pliny, Macrobius, and Martianus Capella. Where these texts mention planetary periods of zodiacal revolution, they assign 30 years to Uranus, 12 years to Saturn, and slightly less than a year each to Mercury and Venus.[139] The statements in the *LW* about the period that each of these planets needs to complete a degree could have easily been extracted from this information *via* an approximation that reckons 360 days for a year. It is not so in the case of Mars, which according to this chapter takes two and a half days to complete a degree, whereas the ancient writers just mentioned agreed on a zodiacal period of approximately two years. The claim made in the *LW* also goes against the data contained in the Toledan Tables and all other astronomical tables available at the time, where the mean motion of Mars is always recorded as $\approx 0;31,26^{\circ/d}$ or slightly greater than half a degree per day.[140]

We encounter another unusual astronomical doctrine in §37, where the position of the Moon, whose ecliptic longitude was the subject of the preceding chapter, is used to measure the distance of one's current latitude from either of the two tropics. The relevant passage, which has no known counterpart in the remaining Latin astrolabe literature, runs as follows:

> *Ut scias ab ipso paralello qui dividit perustam a nostra temperata quoti sint gradus usque ad tuum locum ubi es, Luna posita in primo gradu Cancri apprehende eam in ipso puncto meridiano et quot fuerint gradus supra eius altitudinem usque ad lineam medii celi, tot a prefato paralello habes gradus usque ad te. Item Luna posita in primo gradu Capricorni apprehende eam in medio die et quot supra eius altitudinem sursum habueris gradus, tot a parallelo qui perustam et australem dividit usque ad locum tuum gradus indubitanter habebis*. [*L* f. 93r]
>
> In order for you to know the number of degrees that are between the parallel that divides the torrid zone from our temperate one and your own location, you must seize the Moon at the noon point when it is positioned in the first

> [sic for *stellam] que tibi visa fuerit planeta et firmiter nota. In sequenti nocte easdem altitudines nec plus nec minus acceptas, vide si ipsa quam planetam putabas gradum mutavit. Si mutavit, planeta est. Sin, fixa*.

139 Pliny, *Naturalis historia* 2.32–39 [Rackham 1949, 188–193]; Macrobius, *In somn. Scip*. 1.19.3–4, 2.11.7 [Willis 1970, 73, 128]; Martianus Capella, *De nuptiis* 8.856, 882–886 [Willis 1983, 324, 334–336]; Hyginus, *De ast*. 4.14, 17–19 [Viré 1992, 153, 156–157]; Vitruvius, *De arch*. 9.1.8–10 [Granger 1934, 216–219]; Calcidius, *In Timaeum* 70 [Magee 2016, 232–233].

140 See the table comparing different values in Chabás and Goldstein 2012, 59.

> degree of Cancer. And the number of degrees from its altitude to the zenith [lit. “the line of midheaven”] is the number of degrees between you and the aforementioned parallel. Likewise, seize the Moon at midday when it is in the first degree of Capricorn and the number of degrees that you will have left above its altitude will doubtlessly be the number from the parallel that divides the torrid zone from the southern [temperate zone] to your location.

The technique described in this passage is founded on the insight that the zenith distance of the solstitial Sun at noon will be equivalent to the difference in latitude between the current parallel and the tropic in question (Cancer/summer or Capricorn/winter). Rather than working with the zenith distance of the Sun itself, however, the present rule operates with the Moon at those specific occasions when it is known to occupy the relevant solstitial degree on the ecliptic. The same is true of §51, where the Moon serves as a reference point for inferring the local latitude by adding the obliquity of the ecliptic (24°) to the measured distance between the zenith and the tropic of Cancer—or by subtracting the same from the tropic of Capricorn [see n145 below]. Another case in point is §63, where it is again the Moon, rather than the Sun, whose maximum altitude while in the first degree of Cancer/Capricorn is used to locate the summer/winter tropic in the sky [see n144 below].

Such a preference for the Moon over the Sun might be explained by simple practical considerations: the Moon will reach a given point on the ecliptic more than 12 times as often as the Sun, thus greatly increasing the number of occasions at which the observations described in §37 can be carried out. At the same time, for the technique to work as reliably as suggested in these passages, the Moon would have to be at one of its nodes (and thus have zero latitude) whenever it reaches the beginning of Cancer and Capricorn. While this is obviously incorrect in astronomical terms, an assumption that the lunar latitude reaches zero at these two points is indeed implicit in the *LW*. One hint in this direction comes from §65, which expressly states that an observer located at the summer tropic will see the Moon directly overhead when it is at the beginning of Cancer.[141] Another comes from reading §37 in tandem with §56, which provides a recipe for gauging the width of the zodiac by measuring the difference between the noon altitudes of the Sun

[141] *L* f. 95r:

> *Si fueris sub tropico estivo, ita quod Lunam in capite positam Cancri habes in cent capitis tui.*

and Moon when each is found at the beginning of Aries. This difference is then doubled to obtain the zodiac's total width.

> *Accipe altitudinem Lune dum est in capite Arietis in meridiana linea et serva. Item accipe altitudinem Solis in capite Arietis ad medium diem et nota quot sint gradus inter ambas altitudines numerumque graduum duplica et hunc esse numerum graduum latitudinis zodiaci non dubitabis.* [*L* f. 94r]
>
> Take the altitude of the Moon when it is at the head of Aries [and] on the meridian line and save it. Likewise, take the altitude of the Sun at noon when it is at the head of Aries and note the number of degrees between the two altitudes. Double the number of degrees and you will not doubt that this is the number of degrees of the width of the zodiac.

The rule provided in this chapter seems to rely on two interlocking assumptions. One is that the Moon fully traverses the width of the entire zodiac, such that the maximum lunar latitude can be used to measure this width. The other is that the Moon will have reached this maximum (positive or negative) latitude whenever it is at one of the equinoctial points (the heads of Aries and Libra), which would be required to ensure that its noon altitude at this moment will be greater or smaller than the Sun's by half the width of the zodiac. Assuming this to be case, the points where the lunar latitude reaches zero would necessarily have to be the solstices.

While the precise origin of these ideas remains obscure, a vaguely comparable set of doctrines can be identified in the widely circulated *Computus Gerlandi*, which reached its final stage of redaction in or slightly after 1093. Gerland's computistical treatise incorporates a rudimentary eclipse theory, which was fashioned out of the 19-year lunar cycle of the Latin Easter *computus*. Unaware of the motion of the lunar nodes, which became an established part of the Latin astronomy only in the 12th century, Gerland assumed that eclipses can only occur at two discrete points of the ecliptic. He identified these points with the two equinoxes in Aries and Libra, effectively making them the sole positions at which the lunar latitude reaches zero.[142] The *LW* seems to make the very opposite assumption, namely, that the Moon returns to the ecliptic at the solstitial points.

Some caution in reading this picture of the Moon's motion in latitude into our text is required, however, owing to certain contradictory statements in §63. One of the claims made in this chapter is that only the Moon and Venus are capable of traveling through the entire width of the zodiac, which

[142] See *Computus Gerlandi* 2.14–15 [Lohr 2013, 204–215]. On the background, see Nothaft 2017, 36–46.

is a notion the author could have derived from Pliny.[143] While this basic idea is consistent with the rule given in §56, the author of §63 uses it as justification for why the two tropics must be located with the help of the Moon rather than the Sun. He seems to contradict §56 outright where he states that the Sun and Moon can serve equally well in locating the celestial equator when they are located at the heads of Aries or Libra, which would imply that the Moon's latitude is zero rather than maximum at these points on the ecliptic.[144]

Whoever wrote §63 seems to have believed that the Moon's ability to traverse the width of the zodiac was required for it to reach the two tropics, which is why he considered it the only luminary suitable for identifying the location of these parallels. This would in turn imply that the Sun never actually reaches the tropical circles, not even when located at the beginning of the signs of Cancer and Capricorn. This mistaken view seems to be reflected in §51, which, as was mentioned above, instructs the reader to add or subtract 24° to/from the zenith distance of the Moon when it is at the heads of Cancer or Capricorn in order to find the latitude of one's own geographic position. Surprisingly, the chapter gives a different rule for the Sun, claiming that in its case the addition/subtraction to be made is 12°.[145] It may not be a

143 Pliny, *Nat. hist*. 2.66 [Rackham 1949, 212–215]. See also Martianus Capella, *De nuptiis* 8.882 [Willis 1983, 334]; Bede, *De temp. rat*. c. 26 [Jones 1977, 360–361.15–33].

144 *L* ff. 94v–95r:

> *Item in primo gradu Cancri prendatur Luna noteturque altitudo et ad ipsam celi partem te omni nocti convertes. Quidquid per alhidada de firmamento videris tropicum estivalem esse non dubitabis. Similiter facito de primo gradu Capricorni et habebis tropicum hiemalem. Quod si apprehenso Sole vel Luna in capite Arietis vel Libre idem feceris, diremptorem peruste paralellum respicies. In prioribus quidem duobus paralellis inveniendis Luna utere, quia sola Luna et Venus latitudinem pervagant zodiaci. Medium per Solem nichilominus et Lunam proba. Venus ab hoc opere ideo removetur quia esset laboriosius vel [*sic*] ipsam fieri. Leve est autem per Lunam.*

145 *L* ff. 93v–94r:

> *Si volueris probare in astrolabio aliter item modo quot gradibus distet a capite tuo medium mundi, pone caput Cancri dum Luna est ibi in linea meridiana et numera gradus in almucantarat usque ad cent climatis. Adde XXIIII gradus et habebis latitudinem regionis tue. Item caput Capricorni in linea meridiana constitue et gradus inde usque ad cent climatis numera. Aufer XXIIII gradus et hoc est latitudo regionis tue. Sole ibidem posito, id est in Cancro [*sic*] vel Capricorni*

coincidence that 12° is the width of the zodiac according to Pliny, the same source that described the Moon and Venus as covering this width in its entirety.[146] The same value is mentioned in Bede's *De temporum ratione* in a chapter that vaguely associates the Moon's greatest southern and northern latitudes with the solstices.[147]

Although the matter is far from clear, the puzzling statements in §§51 and 63 may reflect some conceptual confusion between ecliptic latitude, on the one hand, and equatorial declination, on the other. For points on the ecliptic, the maximal declination value is indeed reached at the tropics of Cancer and Capricorn, a fact that the author may have conflated with the maximum width of the zodiac and the latitudes attained by the Moon.

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Astrologie speculationis exercitium.... See Millás Vallicrosa 1942, 316–321.

principio, XII gradus deme vel adde et hoc est latitudo regionis tue.

[146] Pliny, *Nat. hist*. 2.66 [Rackham 1949, 214–215].

[147] Bede, *De temp. rat*. c. 26 [Jones 1977, 360–361.12–34].

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