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From Castile to Istanbul: Moses Ben Abraham de Çivdat and His *Explanation of the Astrolabe with Clear Explanations* (Edition, Translation, and Commentary)

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Abstract

This article presents a diplomatic edition and translation of the only extant manuscript of the *Explanation of the Astrolabe with Clear Explanations***,** a treatise on the uses of astrolabes that the Sephardi Moses ben Abraham de Çivdat composed in the first quarter of the 16th century in Istanbul. I discuss the scanty biographical data that can be gathered from Moses ben Abraham's work as author, translator, and copyist, the sources of his astrolabe text and its technical contents, and Moses ben Abraham's contribution to the knowledge of the astrolabe in Hebrew and non-Hebrew literature. The article underscores Moses' role in creating a continuity between the applied astronomical knowledge of Jews in medieval Iberia and the astronomical teachings and practices of Sephardic Jews in Ottoman lands.

I have organized this monographic study according to the following sections and appendices:

I. Moses ben Abraham de Çivdat: Biographical information and extant work.

II. The instrument codex Paris BnF heb. 1030 and Moses ben Abraham's astrolabe text.

III. Between Castile and Istanbul: Sources and terminology in Moses's astrolabe text.

IV. An all inclusive self-contained handbook on astrolabe uses for Istanbul Jews.

V. Conclusion: Moses ben Abraham de Çivdat—A figure of continuity.

VI. Hebrew Diplomatic Edition of Moses ben Abraham's *Explanation of the Astrolabe with Clear Explanations* in MS Paris BnF heb. 1030 MS, ff. 45b–71a (unique) and English Translation of it

Appendix 1: Abraham Ibn Ezra and al-Ṣaffār on telling the time in seasonal hours with an astrolabe when the position of the sun or its diametrical opposite falls between two hour divisions (Hebrew text and English transl.).

Appendix 2: Abraham Ibn Ezra's and an anonymous treatise on finding the positions of the moon and the planets with an astrolabe by three methods (Hebrew text and English transl.).

Appendix 3: Abraham Ibn Ezra on the longitude of the stars (Hebrew text and English transl.).

Appendix 4: Abraham Ibn Ezra and Ibn al-Ṣaffār on calculating stellar positions with an astrolabe using the star pointers of the rete (Hebrew text and English transl.).

Appendix 5: Abraham Ibn Ezra on the calendar scale on the back of an astrolabe (Hebrew text and English transl.).

Appendix 6: Abraham Ibn Ezra on the calculation of the meridian latitude of the sun when the instrument is not complete and the sun falls between two almucantars (Hebrew text and English transl.).

Appendix 7: Abraham Ibn Ezra on the calculation of the position of the sun when the instrument is not complete and there is no almucantar corresponding to the exact altitude of the sun (Hebrew text and English transl.).

Appendix 8: Hebrew – English glossary of technical terms relating to astrolabes in Moses ben Abraham's treatise (based on the Hebrew text and English transl.).

I. Moses ben Abraham de Çivdat: Biographical Information and Extant Work

Moses ben Abraham de Çivdat seems to be a minor figure in Jewish scholarship, despite his contributions as copyist, translator, and author in four fields: philosophy and Jewish law (copyist), astronomy (translator), and astronomical instruments (author). The different facets of his work are extant in nine manuscripts.[1] He copied in Hebrew and Aramaic in a Sephardic hand and composed only in Hebrew, though it seems that he was proficient in a vernacular language (Castilian) from which he translated a treatise on the solar and lunar eclipses of unknown authorship.

From three colophons, two of them autographs,[2] and five incipits (plus one repetition in the same codex),[3] we can deduce Moses ben Abraham's homeland and the chronological order of his compositions. We know from them that his father (Abraham de Çivdat) and he himself (Moses de Çivdat) were nicknamed "de-Çivdat," *lit.* "of city."[4] They both, father and son, were nicknamed "de-Çivdat" at the same time in MS Paris BnF heb. 1030 (f. 45b).

[1] MSS St. Petersburg National Library of Russia EVR I 320b, Paris Bibliothèque nationale de France heb. 959 and 1030, New York Jewish Theological Seminary of America 6728, Jerusalem National Library of Israel Benayahu O 131, Oxford Bodleian Libraries Opp. Add. Qu. 160, and Jerusalem National Library of Israel Heb. 3982=8, 3961=8, and 3906=8.

[2] MS Paris BnF heb. 959, ff. 76b and 85b.

[3] MS Jerusalem NLI Heb. 3961, ff. 49a and 55b.

[4] I transliterate the Hebrew form as Çivdat rather than Civdat, because the way it was transcribed into Hebrew (Sivdat) makes one think that it was very likely pronounced (and written) with a cedilla (the voiceless alveolar sibilant rather than the voiceless alveolar affricate represented by a plain initial "c" of "ciudad").

The nickname de-Çivdat (written as "de-Sivdat") might very likely refer to Ciudad Real.[5] The early medieval name of Ciudad Real (Kingdom of Castile) was Villa Real. Juan II of Castile (1405–1454) conferred on it the title of "ciudad" on December 22, 1420. Ciudad Real had a Jewish community until 1391, when its Jews either fled to other places or converted.[6] The toponym Sivdat (Çivdat) might also refer to the medieval city Ciudad Rodrigo, which also had a Jewish community.[7] The toponym appended to Moses ben Abraham's name might also have lost the meaning of demonym from a specific Castilian city that it initially had and become only a family nickname.

From some of the colophons and incipits of his texts we also learn that Moses ben Abraham and his father both had an additional name that only emerged in the five copies of the treatise on solar and lunar eclipses, and never in the other texts that Moses copied and authored: "Moses Sahalon (סהלון) ben Abraham Sahalon nicknamed 'de-Çivdat'."[8] and "Moses Sahalon (סהלון), nicknamed 'de-Çivdat'."[9] The form Ṣahalon (צהלון), which seems to be the genuine form of the name (root צ ה ל), is attested only once, in the earliest dated MS.[10] Both names, Çivdat and Sahalon / Ṣahalon, are Sephardic; the former is the standard form for writing the Castilian word "ciudad" ("city") in Judaeo-Castilian, and the latter is the last name of a family of Sephardic Jewish scholars and physicians;[11] it is also found among Jews in Spain in the 14th century in archival sources.[12]

Moses ben Abraham is the copyist of codex St. Petersburg National Library of Russia EVR I 320b (except for ff. 1a–2b) containing a mathematical text by Mordeḵai ben Eliezer Comtino (*Ḥibbur ba-matemaṭiqah*) divided into two sections (*ḥešbon* and *middot*),[13] which

[5] For the identification of Moses ben Abraham as "de Çiudat Real," see Sed-Rajna 1994, 342 (148). See also Vajda (unpublished).

[6] For the Jewish community of Ciudad Real, see Delgado Merchán 1907, 52. The last name "de Cibdad" seems not to have been rare among the population of Ciudad Real. It is found (in full) in a physician of King Juan II of Castille (Fernan Gomez de Cibdad Real, d. 1454) and in a family of conversos judged by the Inquisition in 1482 (Sancho de Cibdad, his son Juan de Cibdad, and other family members); see Beinart 1981, 209 and 251.

[7] See Sierro Malmierca 1990, 23; and García Casar 1992, 73. For these two cities in relation to the Jews, see Beinart and Assis 2007a and 2007b. I thank Javier Castaño, Maria Fuencisla Garcia Casar, Ricardo Muñoz Solla, and Miguel Angel Motis Dolader, for answering my queries about the presence of the last name "de Ciudad" and "Sahalon" / "Ṣahalon" among the Jews in Spain; and Joseph Hacker for his information about these names among the Jews of Istanbul.

[8] MSS Oxford Opp. Add. Qu 160, f. 170a and Jerusalem Benayahu O 131, f. 13a.

[9] MSS Jerusalem NLI Heb. 3906, f. 1a; NLI Heb. 3961, ff. 49a and 55b; and NLI Heb. 3982, f. 22a.

[10] MS St. Petersburg National Library of Russia EVR I 320b, f. 40a.

[11] For the noun "çivdat" in medieval Jewish sources, see *Šeʾeilot u-tešuvot me-rabbi Yosef ben Lev*, vol. 3, no. 104 (online *Responsa Project*); for the name "Sahalon," see Judah ben Asher's responsa, in Cassel 1846, no. 70 (online *Responsa Project*), where a Rabbi Moses Sahalon is mentioned, who is not related to this study and lived in the 14th century. For Ṣahalon, see Klein and Horowitz 2007, 21:444–445, although the article only refers to members of this family starting in the 16th century and outside Spain.

[12] In a private communication Joseph Hacker informs me that Moses ben Abraham de Ciudad does not appear in the available responsa literature of this period, nor in any other printed works, but a certain Moses Ṣahalon is much praised in a paragraph that Joshua Soncino (d. 1569), who was the rabbi of the Sephardi Great Synagogue in Constantinople, wrote in his responsa *Naḥalah le-Yehošuʿa* (printed by his grandson in Constantinople in 1731, no. 28). This Moses Ṣahalon was a highly skilled talmudic scholar and Soncino's student, and the responsa was addressed to him. An identification between this Moses and the Moses of my article is tempting, but since Soncino wrote his responsa in c. 1550, it is highly unlikely that Moses Ṣahalon in Soncino's responsa and Moses Ṣahalon ben Abraham de Ciudad, who was already writing in the last decade of the 15th century (see Table 1 above), are the same person. Could he be a relative of Moses ben Abraham?

[13] This mathematical work is related to the work of the Greek mathematician Nicomachus of Gerasa (c. 6–c.

he copied in May 9th, 1495 in an unidentified place.[14] He is also the copyist of four texts on philosophical topics in the Aristotelian tradition in codex Paris BnF heb. 959,[15] which he copied between November 5th and 15th, 1498 in Istanbul (referred to by the form *Qosṭandinaʾ*, distinctive of Jewish texts). This is known from Moses ben Abraham's autograph colophons in this codex.[16] Georges Vajda considers that numerous marginal and interlineal notes and corrections in this codex (Paris BnF heb. 959) are in Moses ben Abraham de Çivdat's handwriting.[17] Moses also copied an halakhic work by Moses ben Naḥman on the mishnaic tractates *Nedarim* and *Beḵorot* extant in a copy in MS New York, Jewish Theological Seminary 6728.[18] This codex also contains a colophon that mentions Mose ben Abraham as the copyist, but with no indication of date or place.[19]

From the colophons in codices EVR I 320b, BnF heb. 959, and Jewish Theological Seminary 6728 we can deduce that Moses ben Abraham was born in the second half of the 15th century, and that he copied the texts of these codices in his youth, for he calls himself "young" in the three manuscripts: one autograph dated in 9th May 1495 (Comtino's math-

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120 CE); see Steinschneider and Goldberg 1964, 198 [1461–1470]. As regards Comtino/Ḵomaṭiano and his scientific work, see Schub 1932, 54–70.

[14] תם ונשלם על יד הצעיר משה ב<ן> כ<בוד> ר<בי> אברהם צהלון והיתה השלמתו בשנת הרנ"ה בחדש אייר ביום ו' ט"ו בו וכתבתיו לעצמי והשם יפקח לבי להבין כל דבר חכמה ודעת אמן א<מן> א<מן> ס<לה> ס<לה> ס<לה> "The young Moses son of the honoured Rabbi Abraham Ṣahalon finished and completed ⟨it⟩. He finished it the year ⟨5⟩255 ⟨of the World⟩ [= 1495 CE], in the month of Iyyar 15th [= May 9th], Friday. I wrote it for myself. May God open my heart to understand all science and knowledge" (colophon of MS EVR I 320b, f. 40a). All translations in the article and appendices are mine unless otherwise noted.

[15] MS Paris BnF heb. 959, ff. 10a–99a, text nos. 3, 4, 5, and 6. For a description of this codex, see Munk et al. 1866, 168–169 [no. 959], in which it is stated that five treatises of this codex were copied by Moses ben Abraham; Munk 1911, [no. 111]; and Munk 1908, 157–159. The philosophical treatises in this codex are: (1) Levin ben Gershon: Explanation of Ibn Rushd's *Middle Commentary* on Aristotle's books of Logic (ff. 1a–7b); (2) Indications for the student of Aristotle's *Prior Analytics* (ff. 8a–8b); (3) Abraham ben Yom Tov Bibago's commentary of Ibn Rushd's *Middle Commentary* on Aristotle's *Posterior Analytics* (ff. 10a–76b); (4) Hebrew version of Muḥammad ibn Aḥmad Ibn Rushd's *Essay* on Aristotle's *Prior Analytics* (ff. 81a–85b); (5) Hebrew version of Muḥammad ben Yaḥyā Ibn Bājja's (Avempace's) *Letter of Farewell* (ff. 86a–95b); (6) Hebrew version of Aristotle's *Nicomachean Ethics* (ff. 96a–99a); (7) Hebrew version of Muḥammad ibn Aḥmad Ibn Rushd's *Decisive Treatise* (ff. 101a–123a); (8) Joseph ibn Aknin's *Treatise on the Necessary Existent* (ff. 123b–129a); and (9) Hebrew version of Muḥammad ibn Muḥammad al-Ṭūsī al-Ġazālī's *Answers to Questions* (ff. 129b–136a). In fact Moses ben Abraham copied four (nos. 3–6) rather than five texts (the handwriting in ff. 1a–8b is not Moses' handwriting).

[16] ונכתב על ידי הצעיר משה ב<ן> כ<בוד> ר<בי> אברהם דסיבדאט נ<שמתו> ע<דן> פה קושטנדינא רבתי בעשרי<ם> לחשון משנת הרנ"ט לפרט "The young Moses son of the honoured Rabbi Abraham de Çivdat, may his soul be in paradise, wrote this here, in Constantinople the Great, on the 20th of Heshvan [= November 5th], year 259 of the small counting [i.e., 5259 of the World = 1498 CE]" (MS Paris BnF heb. 959, f. 76b) and וכתבתיהו אני משה ב<ן> ר<בי> אברהם די סיבדת לעצמי וסיימתיהו יום ה' ר<אש> ח<ודש> כסליו ל' לחשון משנת ה'רנ"ט "I, Moses ben Rabbi Abraham de Çivdat, wrote it for myself, and finished it on Friday, first day of Kislev [= November 15th], 30th of Heshvan, year 5259 ⟨of the World⟩ [= 1498 CE]" (MS Paris BnF heb. 959, f. 85b).

[17] "Les nombreuses corrections marginales et interlinéaires dans la deuxième partie du volume semblant être de la main du copiste. Au fol. 135v, c'est peut-être encore le copiste qui a ajouté en marge, à l'encre rouge le sense en arabe d'une sentence"; see Vajda (unpublished), 959, who also identified Çivdat as Ciudad Real.

[18] For this codex, see Brumer 1984–86, no. 917 [Hebrew].

[19] נשלמה כתיבת מסכת נדרי<ם> ובכורות להרמב"ן ז<כרונו> ל<ברכה> עם סדר נשים לרבי משולם ז<כרונו> ל<ברכה> ע<ל> י<די> צעיר החברי<ם> משה ב<ן> כ<בוד> ר<בי> אברהם דיסיבדאת ונעתק מספר מטעה מאד "The youngest of the comrades ⟨at the yeshivah⟩, Moses son of the honoured Rabbi Abraham de Çivdat, finished the writing of the tractate⟨s⟩ *Nedarim* and *Beḵorot* by Rabbi Moses ben Naḥman of blessed memory together with that of the order of *Našim* by Rabbi Meshulam of blessed memory, which he copied from a book full of mistakes" (MS New York Jewish Theological Seminary 6728, f. 43b).

ematical text in two sections), the other autograph dated in November 1498 (Ibn Rushd's *Middle Commentary* on Aristotle's *Posterior Analytics*), and another undated (Naḥmanides' commentary on *Nedarim* and *Beḵorot*).

The colophon in Paris BnF heb. 959 (f. 76b) implies that Moses ben Abraham's father, Rabbi Abraham de Çivdat, was already dead in 1498 (as the expression "may his soul be in paradise" shows), and that Moses was living in Istanbul, as were many Sephardic Jews who had left Spain in 1492 or before the expulsion. As the colophon of Moses' copy of Naḥmanides (MS JTS 6728) does not say anything about his father, we can assume that he was still alive, and therefore this text was copied prior to the philosophical collection copied in 1498. As Moses is mentioned as "the youngest of the students ⟨at the yeshivah⟩," we might consider this text as his earliest. We can say with reasonable assurance that Moses started his writing career as a very young copyist of Naḥmanides (before 1495, in an unknown place when his father was alive), of mathematical texts in the Byzantine tradition represented by Comtino (in 1495, when he was "young" and was copying this text for himself, possibly as a student, and while his father was still alive), and finally of Aristotelian commentaries (in Istanbul in 1498 after his father's death). Moses' father must have died some time between the copying of Comtino's mathematical text in May 1495 and before the copying of the Aristotelian commentaries in 1498.

In addition to the excellent introduction to the calculation tools that the uses of an astrolabe requires and that the copy of Comtino's mathematical texts must certainly have provided, Moses ben Abraham's translation from the vernacular of a treatise on the eclipses might have been an intermediate step between his religious and philosophical interests and the emergence of his technical understanding of astrolabes.[20] The incipits of the manuscript copies of this translation provide valuable information to locate it in Moses' biography as a writer. The incipits of MSS Opp. Add. Qu 160 (f. 170a) and Benayahu O 131 (f. 13a), which are identical, provide the clue.[21] The mention of Moses' father as "dear, venerable, and *ancient* Rabbi Abraham Sahalon" implies that his father was still alive. Using this information, the translation should be placed before the copy of the philosophical collection, when Moses was called "young" but his father was already dead (1498), and after the copy of Naḥmanides' texts, when Moses is called "the youngest student ⟨at the yeshivah⟩" but his father was still alive. In Moses' translation of the text on eclipses, Moses is not mentioned as "young," but his father, who was alive, is called "elderly," so this work is in between the two previous and is number three of Moses ben Abraham's extant textual output. At the same time, Moses is already mentioned with honorifics ("the wise and outstanding Rabbi Moses Sahalon"), which shows his high consideration in the Jewish community at the time of this translation.

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[20] MSS Jerusalem Benayahu O 131, Oxford Bodleian Libraries Opp. Add. Qu. 160, and Jerusalem National Library of Israel Heb. 3982, 3961, and 3906.

[21] מאמר נכבד בלקיות שמשיות וירחיות העתיקו מלשון לעז אל לשונינו המקודש הנבון ומעולה ר' משה סהלון בן היקר ונכבד הישיש ר' אברהם סהלון המכונה די סיבדאת "The wise and outstanding Rabbi Moses Sahalon—son of the dear, venerable, and elderly Rabbi Abraham Sahalon, nicknamed *de Çivdat*—translated from the vernacular into our sacred language a very fine treatise on solar and lunar eclipses."

What was the vernacular that Moses ben Abraham translated into Hebrew? The oldest codex (Opp. Add. Qu. 160, 17th century) containing Moses' translation on the eclipses has a Hebrew term (*me-ha-nefilut*, f. 173b) that was translated into Judaeo-Castilian on a marginal note by the same hand (דישקאמיינטו "desqamiento" = old Castilian "descaimiento" = "descaecimiento" meaning "weakness" = modern Castilian "decaimiento" = "caimiento" = technical astrological term Castilian "caída" = English "fall").[22] MS Opp. Add. Qu. 160 and MS Benayahu O 131 are related: one (possibly the former) is the source of the other, which explains the presence of the same marginal note (and the same incipit) in Benayahu O 131, where the same copyist's hand translates in the margin two words of the Hebrew text (f. 17a): מהנפילות (Hebrew *me-ha-nefilut*) and הדיהסאמיינטו (Castilian "ha-dehasamiento"), translated into Judaeo-Castilian in the margin as די הקאיימנטוש ("de aqaimientos" = "of falls"). Given the presence of these Castilian terms in both cases by the same hand of the copyist, the original language of the treatise might have been Castilian and they copied the original note of the author; alternatively, a Jewish copyist whose mother tongue was Castilian or who was using the text in a Castilian context authored the marginal note/s, which was later copied together with the text. Nevertheless, Moses' Castilian nickname "de-Çivdat" and this Castilian word in Hebrew characters (הדיהסאמיינטו) in the body of the text explaining a Hebrew term in the translation confirm a Castilian origin for the author, so Moses must be the translator, independently of the authorship of the marginal note in Castilian.[23]

The title of the treatise on eclipses makes one think that this is an astronomical text, but a quick look at the contents makes apparent that this is an astrological text dealing with the astrological influence of eclipses upon sublunary beings. This is the incipit in the oldest copy, dated to the 17th century (MS Bodleian Opp. Add. Qu. 160, f. 170a):

> It is very well known that the stars that move, which are called planets, and the remaining stars [i.e., the fixed stars] work their movements and their hidden properties on the ⟨four⟩ elements and all the sublunary beings, as Aristotle explained and his followers and the astronomers ⟨maintain⟩. This they cause due to the ray, meaning the rays of their light that reach them [the elements and the sublunary beings]. The proof being that when any planet or fixed star is eclipsed, the power of the eclipsed star is absent from the elements and their compounds.[24]

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[22] For MS Oxford Opp. Add. Qu. 160, see Neubauer and Cowley 1886–1906, v. 1, cols. 904–905; Neubauer, Beit-Arié, and May 1994, cols. 488–89 [no. 2518]; Steinschneider and Goldberg 1964, 207 [1491–1500]; and Steinschneider 1893, 649 (where Steinschneider identifies the vernacular as Spanish and wonders about the identity of "Sivdat" finding a Moses who lived in Villa Real mentioned in Judah ben Asher's *Responsa*). This Moses, however, who by an extraordinary coincidence has also the name Sahalon, lived in the 14th century and might have been an ancestor but was certainly not the Moses Sahalon of this study.

[23] מאמר נכבד בלקיות שמשיות וי[ר]חיות שנמצא כתוב ממו<רנו> ר<בי> מ<שה> סהלון המכונה די סיבדאת ואני הכותב לקטתי גם משאר ספרים מה שנמצא כתוב "Distinguished treatise on solar and lunar eclipses that was found written by our teacher Rabbi Moses Sahalon nicknamed *de Çivdat*, and I, the writer, also collected what is written from other books" (MS Jerusalem NLI Heb. 3982, f. 22a).

[24] דבר ידוע הוא ומפורסם כי הככבים ההולכים הנק<ראים> ככבי לכת ושאר הככבים יפעלו פעולותיהם וסגולותיהם ביסודות ובדברים ההווים והנפסדים כסברת ארסטו וההולכים אחריו וכל התוכנים. וזה יפעלו לסבת נצוצה ר<וצה> ל<ומר> נצוצי אורם שיגיע אליהם. והראיה כי כשיהיה לקות משום ככב מהקיימים או הרצים יהיה חסרון הכח מהככב הנלקה ביסודות או במורכב מהם.

This astrological text places Moses ben Abraham's interests within a scientific curriculum that was typical of late medieval Judaism of Sephardic influence and is in tune with the Aristotelian subjects in the philosophical collection he copied in codex Paris BnF heb. 959. The divinatory character of the text on eclipses is enhanced by the contents of its oldest copy in codex Bodleain Opp. Add. Qu. 160 (17th century), which contains versions of most of the astrological works of Abraham Ibn Ezra, two astrological treatises by Māshāʾallāh, and several astrological texts of unidentified authors.[25] The astrological character of the oldest version in codex Opp. Add. Qu. 160 and Ibn Ezra's influence on it remains in the two successive copies (17th-18th centuries and 1749, respectively) of Moses ben Abraham's text on eclipses: codex Benayahu O 131 repeats texts nos. 6, 7, 8, 10, and 14 of its relative codex Opp. Add. Qu. 160,[26] while codex NLI Heb. 3906 repeats texts nos. 2, 3, 4, 7, 8, 12, 13, and 14.[27] Codices NLI Heb. 3961 and 3982 (1756–1763 and 18th/19th centuries, respectively) follow a different tradition unrelated to Abraham Ibn Ezra and are not so focused on astrology but on other divinatory techniques and magic.[28]

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[25] Codex Oxford Bodleian Libraries Opp. Add. Qu. 160 contains: (1) *Mišpeṭei ha-mabaṭim* (ff. 1b–8b); (2) A. Ibn Ezra's *Rešit ḥoḵmah* (ff. 13a–65a); (3) A. Ibn Ezra's *Sefer ha-ṭeʿamim* (ff. 65a–87b); (4) A. Ibn Ezra's *Sefer ha-moladot* (ff. 88a–117b); (5) A. Ibn Ezra's *Sefer ha-meʾorot* (ff. 118a–126a); (6) *Taḥazit asṭrologit ʿal ḥibburei Ṣedeq ve-Šabbetai be-šanat 4914* (i.e., 1154 in the Julian Calendar) (ff. 126b–128a); (7) A. Ibn Ezra's *Sefer ha-mivḥarim* (ff. 128b–140a); (8) A. Ibn Ezra's *Sefer ha-ʿolam* (ff. 140b–153b); (9) Māshāʾallāh's *Sefer ha-šeʾeilot* (ff. 154a–158a); (10) Māshāʾallāh's *Be-qadrut ha-levanah ve-ha-šemeš* (ff. 158a–161a); (11) A. Ibn Ezra's *Elef paʿamim ʾarbah* (f. 162a); (12) A. Ibn Ezra's *Horosqop* (ff. 162b–164b); (13) A. Ibn Ezra's *Sefer ha-ʿolam* (ff. 165a–167b); (14) *Maʾamar niḵbad be-liquyyot šimšiyyot ve-yeraḥiyyot* (ff. 170a–173b); (15) *Ḥibbur be-asṭrologiah* (ff. 174a–176b); and *Goralot* (ff. 177b–178b).

[26] Codex Jerusalem Benayahu O 131 contains: (1) A. Ibn Ezra's *Sefer ha-mivḥarim* (ff. 1a–11b); (2) *Maʾamar be-liquyyot šimšiyyot ve-yeraḥiyyot* (ff. 13a–17b); (3) *Taḥazit asṭrologit ʿal ḥibburei Ṣedeq ve-Šabbetai be-šanat 4914* (i.e., 1154 in the Julian Calendar) (ff. 18a–19b); (4) *Mišpeṭei ha-mabaṭim* (ff. 20a–21b); (5) Māshāʾallāh's *Be-qadrut ha-levanah ve-ha-šemeš* (ff. 22a–23b); (6) A. Ibn Ezra's *Sefer ha-ʿolam* (ff. 24a–27a); and (7) *Sefer ha-mišpaṭ ʿal tequfot ha-šanim* (ff. 28a–30b).

[27] Codex Jerusalem NLI Heb. 3906 contains: (1) *Maʾamar ha-niḵbad be-liquyyot šimšiyyot ve-yeraḥiyyot* (ff. 1a–2b); (2) fragment of print in Italian and Latin characters relating the lines of the hand to the planets, Hebrew names of the planets with their symbols, spheres, letters, and angelic names related to them (pp. 3a–3b); (3) most of A. Ibn Ezra's *Rešit ḥoḵmah* and parts of his *Sefer ha-ṭeʿamim* (ff. 14a–15b, 112a–123b, and 16a–41a); (4) A. Ibn Ezra's *Sefer mišpeṭei ha-mazzalot* and parts of his *Sefer ha-ṭeʿamim* (ff. 42a–56a); (5) A. Ibn Ezra's *Sefer ha-moladot*, *Tequfot ha-šanim*, and parts of his *Sefer ha-ṭeʿamim* (ff. 57a–79b); (6) A. Ibn Ezra's *Sefer ha-mivḥarim* (ff. 81a–93a); (7) A. Ibn Ezra's *Sefer ha-meʾorot* (ff. 94a–100a); (8) A. Ibn Ezra's *Sefer ha-ʿolam* (ff. 109–101b); (9) A. Ibn Ezra's *Horosqop* (animodar for the year 1160, 4921 known as *Mišpeṭei ha-nolad*) (ff. 110a–111a); and birth records of sons and grandsons of Isaac ibn Ṣahal, sometimes with their horoscopes, from the years 1752–1794 (ff. 56a–b, 74b, 80a, 93b, 100a).

[28] MS Jerusalem NLI Heb. 3961 contains: (1) (Qusṭā ibn Lūqā's *Maʿaseh ha-kaddur*, in Jacob ben Maḵir ibn Tibbon's translation) (ff. 3a–15b); (2) *Hagdarat oreḵ ve-roḥav ha-geografiim ve-hatʾamat ha-mazzalot la-aqlimim* (15b); (3) *Sefer šeʾeilot Tolemi* (ff. 16a–22b); (4) *Leqeṭ asṭrologi-magi* (geomancy, astrological glossary in Arabic-Latin, lunar mansions, talismans according to the stars) (ff. 22a–41a); (5) *Ṣurot ha-ṭilasmaʾot lefi ḥaḵmei ha-teḵunah* (ff. 41b–43a); (6) *Sefer mišpeṭei ha-mabaṭim* translated from Turkish by Galeano or, according to this MS, by Isaac ben Moses ben Ṣahal (ff. 43b–48b); (7) *Sefer Vipeq* translated from Turkish by Isaac ben Moses ben Ṣahal (ff. 50a–53a); (8) *Ḥotamei ha-koḵavim ve-ha-mazzalot* (ff. 54b–55a); (9) *Maʾamar niḵbad be-liquyyot šimšiyyot ve-yeraḥiyyot* (ff. 49a and 55b–58a).

MS Jerusalem NLI Heb. 3982 contains: (1) *Sefer šeʾeilot Tolemi* and *Mi-šnei ʿasar mazzalot* (ff. 1a–13b); (2) *Ha-yad me-arbaʿah eṣbaʿot u-bah yod-vav batim* (ff. 14a–16a); (3) *Goralot* (ff. 16b–21a); (4) *Maʾamar niḵbad be-liquyyot šimšiyyot ve-yeraḥiyyot* (ff. 22a–24b).

TABLE 1: Reconstruction of the possible dates and places of Moses ben Abraham's works[29]

Likely chronological order of his writings	**1st (one MS)**	**2nd (one MS)**	**3rd (five MSS)**	**4th (one MS)**	**5th (one MS)**
Copyist	Naḥmanides on the mishnaic *Nedarim* and *Beḵorot* Hebrew and Aramic (Father still alive) (Moses is the "youngest" of the yeshivah students) (No Rabbi title in Moses' name)	Comtino on the *ḥešbon* and *middot* Hebrew Autograph (Father still alive) (Moses is "young") (He copies for himself, he is a student) (No Rabbi title in Moses' name)	---------	Philosophical collection on Aristotle and Averroes Hebrew Autograph (Father already died) (Moses is "young") (No Rabbi title in Moses' name)	---------
Translator	---------		*On solar and lunar eclipses* From Castilian into Hebrew (His father is still alive but is old) (Rabbi title in Moses' name, very likely added later by the copyist)	---------	---------
Author	---------		---------	---------	On the uses of the astrolabe Hebrew (Moses is called distinguished sage and rabbi)
Date	1480's?	May 1495	After May 1495 and before November 1498	November 1498	First half 16th century?
Place	?	Ottoman territories?	Ottoman territories?	Istanbul	Istanbul?
MS/S	New York, Jewish Theological Seminary 6728, ff. 1a–43b	St. Petersburg, National Library of Russia EVR I 320b, ff. 1a–40a	Oxford, Bodleian Opp. Add. Qu. 160, ff. 170a–173b Jerusalem, Meir Benayahu O 131, ff. 13a–17b Jerusalem, NLI Heb. 3906=8, ff. 1a–2b Jerusalem, NLI Heb. 3961=8, ff. 55b–58a and 49a Jerusalem, NLI Heb. 3982=8, ff. 22a–24b	Paris, BnF heb. 959, ff. 10a–99a	Paris, BnF heb. 1030, ff. 45a–71a

[29] I have not included in Table 1 item no. 2a of MS Paris BnF heb. 1030 (dealing with proofs related to Jacob ben Maḵir's quadrant of Israel) that is very likely Moses ben Abraham's work; this manuscript needs further study to confirm his authorship (and his interventions in item no. 2 of the same codex) but this article is not the place.

Leaving aside two Moses' autographs, five of the remaining seven manuscripts are post-16th century but none of them is Italian or Ashkenazi (they are Sephardic, Byzantine, and Oriental). From the study of the incipits and colophons of Moses ben Abraham's writings, we can assume that he was born in the last quarter of the 15th century (c. 1475), given that he was young in 1495 and did not have the title of rabbi at that time. He started his writings as a scribe of a text typical of the Jewish curriculum (commentaries on talmudic tractates, before 1495), continued with the copy of a preparatory text of the contemporary Byzantine tradition (Comtino on mathematics, in 1495), and later (November 1498) with the copy of philosophical texts in the Aristotelian tradition, which let us guess that the yeshivah curriculum included all of them or used them (although, in general, most yeshivot studied only religious texts). In between the mathematical and the philosophical copies, Moses translated an astrological text from Castilian while he was still a yeshivah student (before 1495).[30] This translation from Castilian into Hebrew only makes sense if it was made outside the Iberian Peninsula: only then would this translation be necessary for Jews who did not understand Castilian (mother language of most of the Jews living in Spain). This implies that Moses' family had left Spain, perhaps when Moses was a child or before, and that he attended a religious school with a Sephardic curriculum (which included Sephardic commentarists, like Naḥmanides, and allowed the reading of Aristotelian and Averroist texts, as well as mathematical/scientific subjects including astrology). However, they were living in a culture (Ottoman Istanbul) in which Castilian was a foreign language for Greek speaking Romaniot Jews. This cultural Jewish group might have been the intended readers of Moses' text on eclipses, so scholarly texts written in Castilian had to be translated into Hebrew to make them available to this and other Ottoman Jewish cultures who did not understand this language, hence Moses' translation of his astrological work.

Moses' last known work (his astrolabe text) is an original text authored by Moses when he was already a rabbi, that is, a scholar and a teacher (he is called the "distinguished sage"), for the honorific "rabbi" is attached to his name.[31] Therefore, this text was written after November 1498 (the date of his previous text, namely, the translation about eclipses), very likely in the first half of the 16th century, and possibly in Istanbul, where he copied his philosophical collection and where his family might have settled after leaving Spain. Moses started his career in Istanbul very likely during the rule of Bayezid II (1481–1512) and wrote his astrolabe treatise during this reign or under the rule of Selim I (1512–1520). The date of Moses' death is unknown and not much more can be found about his life and relationships, at least from the documentation extant. What seems clear is that his astrological translation, which is the work of a young scholar, very likely a student, remains his most popular work according to the manuscript evidence (five copies), clearly in contrast with his original text on the astrolabe, extant in only one copy.

[30] For the cultural interests of the Sephardic Jews in Ottoman lands, see Rozen 2010, 244–277.

[31] Incipit MS Paris BnF heb. 1030, f. 45b: "The distinguished sage Rabbi Moses de Çivdat—may his Rock and Redeemer protect him, the son of Abraham de Çivdat, composed an explanation of the astrolabe with clear explanations."

II. The Instrument Codex Paris BnF heb. 1030 and Moses ben Abraham's Astrolabe Text

I shall now consider what must have been a work of intellectual maturity, his last (extant) work, on the astrolabe, in which Moses is referred to as "sage/magister" (*ḥaḵam*) in the incipit,[32] an honorific only present in this text and in two 18th-century copies of his translation on the eclipses.[33] The only witness of Moses ben Abraham's treatise on the astrolabe is MS Paris BnF heb. 1030.[34] This manuscript in paper (leaf of about 200 mm x 140 mm) displays an early 16th-century Sephardic semicursive script (23 lines per leaf). From the incipit (BnF heb. 1030, f. 45b), we learn that when this text was copied Moses ben Abraham was still alive, because the expression used to refer to Moses ben Abraham implies it ("may his Rock and Redeemer protect him"). This should serve to date more precisely this copy of the astrolabe text to the first decades of the 16th century. Sed-Rajna adds in his catalogue that the codex's provenance is from North Africa or Spain, which I am not able to confirm.[35] Codex Paris BnF heb. 1030 is an anthology of astronomical texts that, according to Georges Vajda, "a été probablement constitué dans un centre juif de l'empire ottoman."[36] The contents are the following:

(1) Jacob ben Maḵir's Hebrew version of Qusṭā ibn Lūqā's Arabic text on the construction of a spherical astrolabe (*Maʿaseh be-kaddur ha-galgal*, ff. lb–22b), (item no. 1).

(2) An unknown treatise of at least 34 chapters, possibly the work of Moses ben Abraham, who compiled texts on instruments and also provided explanations of them. I conclude this from the evidence of what remains of this treatise: Chapter 33 on the construction of an instrument (*Ha-šaʿar ha–33 be-maʿaseh ha-keli*) by Jacob ben Maḵir's that is not the quadrant of Israel that he designed (ff. 25a–28b, item no. 2a);[37] and chapter 34 on demonstrations related to this instrument (*Ha-šaʿar ha–34 be-mofetim ha-meyuḥadim le-zeh ha-keli*, ff. 28b–34b, item no. 2b), which is clearly by Moses ben Abraham given the similarities it has with the demonstrations and style in his treatise on the uses of the astrolabe (item no. 4).[38]

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[32] MS Paris BnF heb. 1030, f. 45b.

[33] MSS Jerusalem NLI Heb. 3906, f. 1a, and NLI Heb. 3961, f. 55b.

[34] Microfilm F 15722 of the Institute of Microfilmed Hebrew Manuscripts (IMHM) at the National Library of Israel.

[35] For a description of codex Paris BnF heb. 1030, see Munk et al. 1866, 187 (no. 1030); and Munk 1911 [no. 60]. See also Sed-Rajna 1994, 342 (no. 148); Vajda (unpublished); and Steinschneider and Goldberg, 1964, 207 (given as "Moses Sahlun ben Abraham").

[36] Vajda (unpublished).

[37] Incipit item no. 2a (f. 25a): קח לוח עגול באי זה גודל שתרצה שים מרכז ונקודת ה' ונקוה עליו עגול א'ב'ג'ד' והוא יהיה עגול משוה. ונניח מהלוח חוץ מהעגול מרחק מה שיוכל לצייר בו מה שנבאר ונוציא בו שני קטרים יעמדו זה על זה על זוית ישרה והם זויות א'ה'ג' ב'ה'ד'. ומשכם חוץ מעגול א'ב'ג'ד' עד שפת לוח אחר כח לקבל רבע מרבעי א'ב'ג'ד' לצ' חלקים ויהיה נקודת א' מזרח וב' מערב וקטר א'ג' שמקום עגול חצי היום וקטר ב'ד' במקום אופק השווי.

[38] Incipit item no. 2b (f. 28b): הנה יעדנו לבאר דרך הר' יעקב ב"ר מכיר להוציא מרכז עגול המזלות ויתר העגולים הנוטים העוברים על שתי נקודות טלה ומאזנים. נשים עגול המשוה א'ב'ג'ד' וקטריו שיחתכו בזוית נצבה, הן א'ג' ב'ד' והמרכז ב'. ונשים א'ח' כמו הנטיה ונוציא קו ב'ח' הישר ונמשכהו עם ב'א' עד שיפגשו בנקודת מ' ונשי<ם> גם כן ג'ה' כמו הנטיה. ונוציא קו ב'ה' ויחתוך קטר ג'כ' על ל' ונשים ד'ז' ככפל הנטיה ונוציא קו ב'ז' הישר ונחתוך ב'א' על ט', ואומר שט'ב' הוא לט'מ' ולט'ל'. המופת הנה זוית א'ב'ג' נצבה להיותה בחצי עגול וזוית ח'ב'ה' שוה לזוית א'ב'ג' לשווי הקשתות שהן התושבות. אם כן זוית מ'כ'ל' נצבה להיותה גם כן בחצי עגול וזוית ח'ב'כ'

(3) An unidentified and acephalous text on the geometry of the circle (ff. 35b– 41b, item no. 3).[39]

(4) Moses ben Abraham de Çivdat's text on the astrolabe that is the subject of this article (ff. 45b–71a, item no. 4).

(5) Mordeḵai ben Eliezer Comtino or Ḵomaṭiano's explanation of the construction of the plate *ṣafiḥah* (*Tiqqun luaḥ ha-ṣafiḥah*, ff. 75a–80a, item no. 5).

(6) Jacob ben Maḵir's Hebrew version of Azarquiel's treatise on the construction of the plate *ṣafiḥah* (*Iggeret ha-maʿaseh ba-luaḥ ha-niqraʾ ṣafiḥah*, ff. 83b–100b, item no. 6).

(7) Jacob ben Maḵir's Hebrew version of Ibn al-Ṣaffār's treatise on the use of the astrolabe in forty chapters (*Peiruš ha-asṭrolab*, ff. 107a–113b, item no. 7).

(8) Chapters 1–3 of Jacob ben Abi Abraham Isaac al-Corsuno's treatise on the construction of astrolabes in 8 chapters (f. 114a), which the catalogues refer to as anonymous, but which I have identified (item no. 8). The third chapter of this treatise, which is incomplete, presents several differences with respect to the published edition of Corsuno's text.[40] This text is at the end of the codex, but the blank verso (of this folio f. 114b) makes clear that the five remaining chapters of Corsuno's treatise and what is missing of the third were not lost before the binding of codex Paris BnF heb. 1030; they were never copied.

One hand (first half of the 16th century) wrote items no. 1–6 (with an appendix added by a different hand on f. 41b), and a later hand (mid-16th century) wrote items no. 7–8.[41] The codex was at some point bound with two early printed works unrelated to instruments that were printed in Ferrara in 1556 and whose disappearance was noticed in 2000.[42] The second script (items nos. 7–8) seems to have some Italian elements or influence; it might be

גדולה מזוית כ'ב'ה' ככפל זוית ח'ב'א' להיות ... Explicit (f. 34b): וזהו מה שרצינו ביאורו. נשלמו כל המופתי<ם> המיוחדי<ם> בזה הכלי, עוד ביארנו דברי<ם> בלתי מיוחדי<ם> לו להיותם עמוקי<ם> מאד ובלתי מבוארי<ם> בספר מי שקדמנו. והתהלה לאל ית<ברך>.

[39] Incipit item no. 3 (f. 35b): כאשר היו שני קוים ממשלש על תושבת אחת והיו שתי הזויות שאצל התושבת אין בהן זוית נדוחת אומר שהן מקיפין בזוית גדולה מן קוי המשלש שעל זו התושבת אשר יוסיף כל אחד ככח על גילו מקוים הראשונים שטח אחר בעינו. Explicit (f. 41b): וזה שקו ה'ג' הוא נראה מזוית ח'ה'ג' וקו ד'ג' הקצר ממנו יראה מזוית ד'ח'ג' שהיא יותר גדולה. וכן יתבאר שכל מה שקרב לנקודת כ' יראה יותר גדול.

[40] See Rodríguez-Arribas 2018, 27–82 (Hebrew edition available only online at https://journals.sagepub.com/doi/suppl/10.1177/0021828618755773). When I published my edition of Corsuno's text I had not identified this manuscript fragment yet.

[41] The database of the NLI dates the scripts to 14th (texts nos. 1–6) and 15th centuries (texts nos. 7 and 8), while Munk rightly dates all them to the 16th century (Munk et al. 1866, 187), just like the BnF Catalogue online ⟨https://archivesetmanuscrits.bnf.fr/ark:/12148/cc76764⟩, accessed 24th December 2021. Vajda also dates the manuscript to the 16th century, see Vajda (unpublished), but Sed-Rajna dates it to the 15th and 16th centuries (perhaps in Spain or North Africa), see Sed-Rajna 1994, 342 (no. 148). Given that Moses ben Abraham was clearly active during the last decade of the 15th century (he was copying several texts in 1498 and he is called "young" in the two colophons above mentioned of MS Paris BnF heb. 959, ff. 76b and 85b), it is impossible to maintain either a 14th-century or an early 15th-century hand for the copy of Moses ben Abraham's treatise on the astrolabe in MS Paris BnF heb.1030; this hand must be necessarily from the first quarter or first half of the 16th century.

[42] See Munk et al. 1866, 187 (no. 1030), and BnF Catalogue online ⟨https://archivesetmanuscrits.bnf.fr/ark:/12148/cc76764⟩, accessed 24th December 2021. The two printed works are: Naḥmanides' *Šaʿar ha-gemul* and *Kavod Eloqim*.

that the scribe of these two texts was working in Italy in the mid-16th century and it was he who added the printed texts to the compilation.[43]

The oldest and longest part of codex Paris BnF heb. 1030 is a consistent collection of texts explaining the construction of four astronomical instruments: the spherical astrolabe (item no. 1), planispheric astrolabe (item no. 8), *ṣafiḥa* (texts no. 5 and 6), an unidentified instrument (item no. 2a–2b). In addition, it includes two texts explaining the uses of the planispheric astrolabe (items no. 4 and 7), and a theorical text on the geometry of the sphere (item no. 3)—essential for the construction and the use of any astronomical instrument. The authors represented in the collection of this codex are the most representative of instrument knowledge among Jews. Jacob ben Maḵir ibn Tibbon (ca. 1236–1307), in southern France, translated into Hebrew Abū al-Qāsim Aḥmad ibn al-Ṣaffār's text on the use of the astrolabe and authored a text on an instrument of his invention, the quadrant of Israel. Mordeḵai ben Eliezer Comtino or Ḵomaṭiano (1402–1482) authored in Constantinople several treatises on the use and construction of instruments, among them one on al-Zarqālī's universal instrument (the *ṣafiḥah*). The Andalusians Ibn al-Ṣaffār (d. 1035) and al-Zarqālī (1029–1087), and the Syrian Christian Qusṭā ibn Lūqā (820–912) authored Arabic texts on instruments that had been very popular in different Hebrew translations since the 12th century. Jacob ben Abi Abraham Isaac al-Corsuno (fl. second half of the 14th century) authored a treatise on the construction of astrolabes in Arabic (Seville 1376) that he later translated into Hebrew (Barcelona 1378). All of them are present in this codex with a treatise related to a mathematical instrument. My hypothesis is that items 1–6 were copied in codex Paris BnF heb. 1030 by a disciple of Moses ben Abraham while he was still alive and he copied them from a codex that Moses himself compiled and commented on (as item no. 2b clearly shows). Later a different hand added items 7–8.

The manuscript of Moses' astrolabe text in twenty-eight chapters presents nine or ten types of interventions by users (given that some of the interventions are just a mark, a letter, or a word, it is not always easy to distinguish them or their corresponding hands). This means that it was consulted, commented, corrected, and carefully read by several readers (aside from the copyist) who actively engaged with the text (plus those readers who read it but did not leave any visible mark in the manuscript):

[43] I thank Ilona Steimann for helpful additional comments regarding this codex.

TABLE 2: Different reader interventions in the manuscript of Moses ben Abraham's astrolabe text

Reader interven-tion[44]	**Distinctive mark**	**Kind of intervention**
1 (the scribe)	-------	Introduced chapter numbers 1–19 in Hebrew alphanumeric characters on the margins of the manuscript with black ink. Most of these alphanumerics carry on top of the number an ornamentation of horizontal and vertical short strokes identical to or resembling the ornamentation of the catchwords present at the bottom of all the folia on verso of the manuscript. Introduced a marginal note (f. 45b) with a script that is identical to the hand of the copyist, so it must be the copyist.
2	(⊣) only to indicate the insertion of the corresponding marginal note, not to indicate the other interventions.	Introduced marginal notes and additions (ff. 47a, 59b, and 61b). Introduced short interlineal additions (on ff. 46a, 46b, 47a, 48b, 49a, 49b, 56b, 57b, 58a, 61a, 65a, 66a, 68a, and 69b). Introduced interlineal corrections of letters and one or several words (on ff. 45b, 48a, 51b, 52b, 60a, 60b, 62a, 63b, and 70a).
3	(⟜) on top of the corresponding word in the text to indicate the place of the insertion of the marginal note. This sign is never used again on the manuscript.	Introduced a marginal note (f. 46a) only once.
4	(:) above and (:) below the line to separate between two words. This sign is never used again on the manuscript.	Indicate a separation between two words (f. 46b) only once.
5a	(·) writing a dot above and below the letter to indicate it as wrong, only once	Marked (rightly) a mistake with a dot above and below the letter (f. 47a and 60b).
5b	(·) writing a dot above one or several letters of the word to indicate the word as wrong	Marked (rightly) a mistake with one or several dots above (ff. 59a, 63b).
6	(´) on top of the word or characters of the word.	Indicated corrections of words and letters (rightly on ff. 47a, 48a, 51a, 54a, 64a, 65a, 65b, 66a, 67a, 67b, and 70a). There are indications of a mistake when there is no mistake (ff. 55a, 60a, and 64a).
7a	(⁚) above a word and (·) on the next to it to indicate rightly an exchange in their order.	Interlineal mark to indicate alteration in the order of two words (ff. 48b, 52b, 55a, 56a, 59a, 60b, 61a, 62b, and 64a).
7b	(⁚) above a word for unknown reasons or to indicate mistake	Interlineal mark for unknown reasons when the word is correct (ff. 48b, 52a, 55a, 60a, 64b, 67a, and 67b). When there is a mistake in a character of the word (f. 62b).
7c	(⁚) between two words to indicate separation between them	Indicating separation (f. 60a).
8	---------	Introduced chapter numbers 20 and 22–23 in the margins with red ink (ff. 59a, 61a, and 62a). Chapters 21 and 24–27 are unnumbered in the margin, according to the copyist's original layout.
9	(⁚) above the line to indicate the insertion of marginal or interlineal additions or corrections by different hands	Marked the insertion of marginal/interlineal additions or corrections with two dots (ff. 61b, 62a, 62b, 64a, 64b, and 70b).
10?	--------	One of the previous hands or an additional one added a final word (תם?) and a sentence at the end of the manuscript as its colophon.

[44] The interventions are arranged and numbered not according to the chronology of the script (which is impossible to know in most of the cases) but according to the order in which they appear on the manuscript text.

Hand two seems to have been the most active in interacting with the contents of the manuscript, and the most expert in his corrections, although there is no evidence supporting his consultation of another manuscript of the text. Hand seven is also very active, but some of his interventions are marks whose meaning is not clear.

Either copyist, one of these hands, or an additional and different one was the author of the seven technical diagrams of circles and triangles in three different combinations of colors: brownish ink for the lines and arcs and red ink for the letters on Diagram 1 (f. 63a); red ink for the lines and green ink for the letters of Diagrams 3 and 6 (ff. 68a and 70b, respectively), and brown ink for the circumference in Diagram 3; greenish ink for the lines and red ink for the letters on Diagrams 2, 4, 5, and 7 (ff. 63b, 68b, 70a, and 70b, respectively), but alternating red and brown inks in the letters of Diagram 2 and green and red inks in the letters of the word "second" in Diagram 4 (Diagram 4a of my translation). Only Diagrams 1, 2, and 3 (ff. 63a, 63b, and 68a, respectively) seem to have been anticipated, for the copyist left some space for them within the page. The remaining four diagrams (Diagrams 4, 5, 6, and 7) were drawn in the margins and were added by someone who was closely following the explanations of the text, for the same letters for points and lines of the text have been used in the corresponding diagrams. They might have also been copied from the original codex that Moses ben Abraham wrote. The same hand of these diagrams might have drawn the technical diagrams of triangles and circles on the acephalous text on spherical geometry in the same codex (item no. 3, ff. 35b–41b) and in chapter 34 (item no. 2b, ff. 28b–34b) of the text related to Jacob ben Maḵir (item no. 2a, ff. 25a–28b). The copyist of item no. 2b clearly copied the diagrams from his model because his script left space within the text to cleanly place the diagrams. The opposite must be said of item no. 3, where the diagrams, as in item no. 4, were introduced after the script and without a plan, for all of them are placed in the margins (exception on f. 40b where enough space was left for the circular diagram). Some of the diagrams on item no. 3 were cut when the manuscript was trimmed to make the codex. Items no. 1 and 5–8 do have neither diagrams nor blank space left for them.

The presence in the codex of the so far obscure name of Moses ben Abraham and his unique text connected to these illustrious names and their instrument texts is unexpected. Salomon Munk and Georges Vajda thought that Moses ben Abraham's treatise on the astrolabe was or might be incomplete.[45] A perusal of the text makes clear that the text is not only complete but displays one of the most thorough explanations of the uses of an astrolabe in the Hebrew language. Furthermore, the text is accurate, displays a taste unusual in instrument books for the amount of detail in the descriptions, and does not present as many copying mistakes as the frequent use of one or more letters to tag points, lines, and triangles in the diagrams and to denote numbers in specific calculations (examples) would cause one to expect. These features might justify its inclusion in the codex as a companion to other texts on astronomical instruments that were far more prestigious than it was. We do not know anything, either, about the specific circumstances of Moses' astrolabe text. Given the paucity of the historical information we have about Moses ben Abraham and the

[45] Munk et al. 1866, 187 [no. 1030], and Vajda (unpublished), [1030].

specific context of his astrolabe text, the text itself might contain clues about his education, interests, and sources.

III. Between Castile and Istanbul: Sources and Terminology in Moses' Astrolabe Text

The fact that Moses mentions neither Latin nor Arabic sources by name (with the exception of Azarquiel) in his treatise must be interpreted as a clear sign that he intentionally drew from sources, either original or translations, available in Hebrew, but no other language, perhaps with the intention of making them accessible for his students, who necessarily would understand Hebrew, but whose knowledge of other languages known or spoken in Istanbul (Arabic, Greek, Castilian, etc.) was more uncertain.[46] His knowledge of Castilian, as his translation of the anonymous text on the eclipses shows, might have facilitated the consultation of astrolabe sources in this language—for instance, the *Libros del saber de astrología* by Alphonse X (13th century), among which is a treatise on the uses of astrolabes—but there is no indication in the contents of the manuscript or in its language of Moses' use of sources or authors in this language.

Two main strategies are used in this section to detect and discuss Moses ben Abraham's sources for his astrolabe text: the explicit mention of authors and books in Moses' treatise and the technical terminology displayed in Moses' explanations. The identified sources on the uses of astrolabes available in Hebrew at the beginning of the 16th century when Moses wrote his text are several (I omit here the anonymous ones, such as texts attributed to Ptolemy): Abraham Ibn Ezra (1089–1164) and his three Hebrew versions of his astrolabe text, Aḥmad ibn al-Ṣaffār's text in Jacob ben Maḵir's Hebrew version (1236–1304), Emmanuel ben Jacob Bonfils of Tarascon (c. 1300–1377), Jacob ben Abi Abraham Isaac al-Corsuno (fl. second half of the 14th century), Solomon Franco's text (second half of the 15th century), Mordeḵai ben Eliezer Comtino (1402–1482), at least one of the Hebrew versions (15th century) of *De mensura astrolabii* composed by Hermann Contractus (1013–1054), Eliyahu Cohen of Montalto (15th century), and Moses' contemporary in Ottoman lands Joseph ben Solomon Ṭaiṭaṣaq (1465?–1545?). Moses' sources are Andalusian and Sephardic or related to the Sephardic tradition (with the exception of one Byzantine source, Mordeḵai Comtino).

Joseph ben Solomon Ṭaiṭaṣaq was a contemporary of Moses and they might have crossed paths in Ottoman lands. However, there is no evidence of Ṭaiṭaṣaq's idiosyncratic astrolabe in Moses' text. Furthermore, Ṭaiṭaṣaq dealt with construction while Moses is only concerned with its uses and their proofs. There is, however, a short section related to

[46] If Vajda is right about the marginal note in MS Paris BnF heb. 959, fol. 135 in Judaeo-Arabic and that Moses is its author, he must have known Arabic, not as his mother tongue, which was Castilian, but which he might have learned in Istanbul where Arabic was one of the languages of culture, especially scientific culture, although the Turks spoke Turkish (greatly influenced by Arabic and Persian). For the above-mentioned Arabic note in MS Paris BnF heb. 959, see Vajda (unpublished), 959. According to the evidence of Moses' astrolabe text, he very likely read all his astronomical sources translated in Hebrew rather than in their original Arabic language.

construction in Moses' text that coincidentally provides a solution for one of the components missing in Ṭaiṭaṣaq's astrolabe treatise: how to construct a calendar scale on an additional piece of paper or parchment when the astrolabe one owns does not display one (II.3 ⟨1⟩–⟨15⟩). One of the idiosyncratic features of Ṭaiṭaṣaq's astrolabe was that there was neither a calendar scale on his treatise, nor instructions for constructing one. Moses provides a solution for this circumstance, though he does not provide instructions for determining the eccentricity of the calendar, which he clearly describes as eccentric (II.3 ⟨4⟩) and with the vernal point at March tenth (II.3 ⟨11⟩).[47]

Moses ben Abraham mentions only two astrolabe authors by name: Abraham Ibn Ezra and Rabbi Mordeḵai (sic), that is, Mordeḵai Comtino. Ibn Ezra is quoted almost literally on a couple of occasions, and more freely in a few more; sometimes his name is not even mentioned but the terminology gives proof of his influence. Comtino is explicitly mentioned twice. Moses draws from Ibn Ezra's second Hebrew version (and to a lesser degree the third); and might have drawn from a non-extant text on the uses of astrolabes by Mordeḵai Comtino, of which Moses' text might be a witness. Abraham Ibn Ezra seems to be the most visible and widespread influence in Moses' treatise. Moses mentions him by name in one of the methods to tell time in seasonal hours (IV.2 ⟨4⟩–⟨5⟩, which continues in IV.3 ⟨1⟩–⟨14⟩), in the placing of the positions of the stars in longitude on an astrolabe (XVIII ⟨1⟩, cf. Appendix 3 of the article), and in the calculation of the zodiac latitude of any fixed star (XIX.2, method explained in XIX.1); Moses refutes the two last methods.[48]

Mordeḵai Comtino is also mentioned twice by name (as Rabbi Mordeḵai in XVIII ⟨1⟩ and XIX.2 ⟨3⟩). The first mention concerns his method of placing the fixed stars on the astrolabe according to their longitude, which Moses refutes. Rabbi Mordeḵai is referred to with the formula "may his rest be in the Garden of Eden," as was customary after the name of a deceased person. The use of this expression to refer to Comtino means that Comtino was already dead when Moses composed his text; it is possible that Moses met him, but Moses must have been very young (and perhaps still in Spain) when Comtino died (1482). The second time Moses mentions Comtino is in relation to the determination of the zodiacal latitude of any fixed star (explained in XIX.1 and XIX.2, with the mention of Comtino in XIX.2), again together with Abraham Ibn Ezra. It is not clear why Moses put Ibn Ezra's and Comtino's methods side by side, for the former wrote only on the uses of astrolabes and explained how to calculate stellar positions with an astrolabe, but did not devote any commentary to the construction of the star pointers; while the latter wrote only about the construction of astrolabes and explained the placing of the star pointers, but never referred in his extant texts to the use of the star pointers in calculations with astrolabes. Comtino might have written a text on the uses of astrolabes that is not extant but was still available

[47] For Ṭaiṭaṣaq's astrolabe text and its features, see Rodríguez-Arribas and Kozodoy 2020.
[48] For the method of Ibn Ezra that Moses is following, see Appendix 4, either the first or the second versions. Moses has greatly truncated his source so that the identification of the version is not easy; it could be either of them. Ibn Ezra's explanation in the two versions is much longer and gives alternative methods for these calculations, which Moses omits. For Abraham Ibn Ezra's *Keli ha-neḥošet*, I have used manuscripts of the three versions of his treatise on the astrolabe. I obtained access to a PhD dissertation with the Hebrew edition of these texts (Eichenbaum 2021) only when the article was finished.

in Moses' times,[49] but it seems unlikely that Ibn Ezra wrote a treatise on the construction of astrolabes unmentioned by even one source. Moses ben Abraham is harshly critical of the two main authors of astrolabe literature in Hebrew who worked in the Sephardic tradition and took mainly from Arabic sources. Ibn Ezra and Comtino were themselves very critical in their respective approaches to the instrument (we have already quoted Ibn Ezra's remarks, see Appendices), and Comtino, despite being a passionate admirer of Ibn Ezra's works, criticised Ibn Ezra's texts on the astrolabe and tried to perfect them in his own work.[50] It is known that Comtino taught mathematics and astronomy to Eliyahu ben Abraham Mizraḥi (c. 1445–1525),[51] the religious head of the Jewish community in Istanbul (since 1500) whose yeshivah instructed students in religious as well as in secular studies.[52] If one of the readers of Moses' treatise was Eliyahu Mizraḥi, Moses ben Abraham might have been interested in mentioning Eliyahu's prestigious teacher. Furthermore, Moses might also have had access to additional oral sources on astrolabes coming from Comtino (for example, on the uses of astrolabes) via one of his disciples, perhaps Eliyahu himself, which would explain the absence of any written source by Comtino on this specific topic. There is no extant text by him on the use of astrolabes, but he might have taught about it.

Two features define Moses' choice of astrolabe-related terminology. Firstly, he seems to have collected the best terminology currently available. This might explain his use of synonyms several times in different contexts (for the astrolabe, the alidade, the limb, etc., see Glossary in Appendix 8), which indicates that Moses absorbed information from different sources, Sephardic and non-Sephardic, which his terminology mirrors. Secondly, despite his gathering of technical terms from various sources, he is exceedingly accurate in the use of them. Moses employs Abraham ibn Ezra's terminology ("first preservation" and "second preservation") in the calculation of the ascension of a zodiac sign for a given local horizon when there is no latitude plate for the local horizon of the calculation (XII.3 ⟨4⟩–⟨9⟩). Ibn Ezra uses the distinctive terms "first preservation" and "second preservation," exclusive to him, in his second version of the astrolabe text (in the same calculation),[53] and in different contexts in his two other Hebrew versions on the astrolabe.[54] Moses' choice of technical terms in his treatise confirms and enlarges Ibn Ezra's influence (see Appendices).[55] Moses ben Abraham's expression "mark on the limb with the beginning of Capri-

[49] As regards Comtino's approach to the construction of the star pointers of the rete, see his treatise on the northern astrolabe, MS Paris BnF heb. 1095, ff. 135b–138b.

[50] See the introduction of Comtino's treatise on the northern astrolabe, MS Paris BnF heb. 1095, f. 123a.

[51] About Mizraḥi's scientific interests, see Langermann 2011, 446–449.

[52] Levy 1994, 38 (and the bibliography quoted there). In Salonica, where Joseph ben Solomon Ṭaiṭaṣaq was also the head of a yeshivah, the Jewish community supported a school for secular studies (medicine, astronomy, and natural philosophy), Levy 1994, 37–38.

[53] See MS Paris BnF heb. 1045, f. 191b–192a.

[54] The noun שמור with the meaning of "preservation" is used in several contexts in the third version of Ibn Ezra's astrolabe text (for instance, MS Moscow Russian State Library Günzburg 937, f. 11a, explaining the astrological directions). The term is missing in any context in the first Hebrew version of his astrolabe text (MS Paris BnF heb. 1053).

[55] For Abraham Ibn Ezra's three texts on the astrolabe (plus the Latin version), see Rodríguez-Arribas 2014. For the terminology of the astrolabe in the 12th century and Ibn Ezra's strategy vis-à-vis the terminology of the astrolabe in Arabic, see Rodríguez-Arribas 2016. Some of the terms that Ibn Ezra introduced in astrolabe literature in Hebrew are *afudat ha-mazalot, beriaḥ, maʿeṣar, gevul, daf, zanav, merkaz, keli neḥošet, mešaret, samut,*

corn" (IV.3 ⟨8⟩–⟨9⟩) mirrors Ibn Ezra's use of it (*saman ʿim roš Gedi*) in all of his three treatises on the astrolabe.[56] Moses also uses the Hebrew word *mešartim* to denote "planets" (XIII.1 ⟨2⟩), which is distinctive of Abraham Ibn Ezra.[57] *Mešartim* is used only in the second version of A. Ibn Ezra's text on the astrolabe,[58] which provides yet more evidence that Moses ben Abraham knew the three versions but used, above all, the second Hebrew version of Ibn Ezra's astrolabe text (see Appendices).[59] One more Hebrew term that is distinctive in Abraham Ibn Ezra and that Moses uses is *gevul* ("clima," in XIII.4a ⟨1⟩).[60] Finally, Moses' introduction of the technical term "power" (*koaḥ*) in an intriguing sentence related to the astrological houses and with astrological scope (XXVII.3c ⟨2⟩) implies that Moses was familiar with astrological works in which this term was used, very likely Ibn Ezra's works. Ibn Ezra used it profusely in different connotations, though Bar Ḥiyya and others also used it with the general meaning that Moses does: "The power (*koaḥ*) of the eastern side changes into the power of the western side and the visible part in the east is the ascendant."[61] The term is not used in Abraham Ibn Ezra's Hebrew treatises on the astrolabe with an astrological meaning, so Moses must have found it in the abundant astrological literature available in his time. He might have used this Hebrew term with the meaning of "hidden property," which is one of the distinctive meanings of this term in contexts of natural philosophy.

As Moses uses, among others, one distinctive term to denote the astrolabe (*keli habaṭah*), he also must have known some of the texts (about 30 MSS) that used this distinctive expression to name the astrolabe. A group of them (the largest, ca. 15th century) deals with its construction and is attributed to Ptolemy, and another group is focused on the proofs (*mofetim*) of the construction and is also related to Ptolemy, but translated from Greek into Hebrew by the Romaniot Solomon ben Eliyah Sharviṭ ha-Zahav (late 14th century).[62] Another technical term pointing out a possible specific source is *ṭabur* (centre, hub) used by Moses to denote the centre of the Earth (I.1 ⟨4⟩) or the centre of the astrolabe (III.1 ⟨5⟩). Mordeḵai Comtino uses this term in his treatise on the northern astrolabe to denote the centre of the astrolabe.[63]

Moses mentions other specific sources by name in relation to very particular aspects of astrolabe use. Abraham bar Ḥiyya's *Book of the Calculation of the Motions of the Planets* (seventh chapter) is brought up in relation to a method to calculate the altitude using either

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qav qodqod, rešet, svaḵah, and *teliyyah*; all of them are in Moses' treatise.

[56] Cf. Moses ben Abraham's expression סמן עם ראש גדי (for example in IV.3 ⟨8⟩–⟨9⟩) and Ibn Ezra's סמן עם ראש גדי in his first Hebrew version (MS Paris BnF heb. 1053, f. 8b), שים סימן עם ראש גדי in his second Hebrew version (MS Paris BnF heb. 1045, f. 191a), and עשה סימן בחיק עם ראש גדי in his third Hebrew version (MS Günzburg 937, f. 5b).

[57] For Ibn Ezra's technical terminology in his astrolabe treatises, see Rodríguez-Arribas, "Reading Astrolabes in Medieval Hebrew," 89–112, especially 93–94 and 96–105.

[58] See MS Paris BnF heb. 1045, ff. 188b, 189b, 190a, 192b, et cetera.

[59] The third version is rather different (also in the language) from the first and the second ones; see Rodríguez-Arribas 2014, 237–249.

[60] See Sela 2019, 358–359, which revisits his previous study in Sela 2003, 107–112.

[61] In relation to *koaḥ* and its relevance in medieval stellar sciences, see Rodríguez-Arribas 2015, 340–345.

[62] For Eliyah Sharviṭ ha-Zahav, see Goldstein 2020, 129–159, especially at 13 and 15; and Goldstein 1979, 36–37.

[63] For Comtino's term, see MS Paris BnF heb. 1095, f. 125b.

of the two shadows (XXIII.8).[64] Moses quotes Euclid seven times: Book I, proposition 34 (XIII.4b ⟨8⟩) and Book VI (XIII.4b ⟨14⟩), both in the context of a practical example illustrated with a diagram (Diagram 1) that explains how and why the right and inverted shadow work; he also quotes Book I, proposition 29 (XVIII.1 ⟨7⟩) and Book VI, proposition 4 (XVIII.1 ⟨9⟩) in relation to the angles of the triangles in a calculation that he also illustrates with a diagram (Diagram 3) to demonstrate which angles are equal and which are right and how two triangles are similar. Finally, Moses ben Abraham refers to Book 5, propositions 24 (XXVIII.6b ⟨11⟩), 11 (XXVIII.6b ⟨13⟩), and 8 (XXVIII.6b ⟨14⟩) in the context of an indirect proof at the very end of his treatise. Theodosius of Bithynia's *Sphaerica* (ca. 100 BCE) is mentioned in relation to the principle of spherical geometry that two great circles of the sphere bisect one another (II.7 ⟨3⟩). Azarquiel or al-Zarqālī (1029–1087) and Ptolemy (2nd century) are the sources mentioned for two possible values of the inclination of the ecliptic or solar path: 23;33º or 23;51º, respectively (VIII.2 ⟨1⟩).[65] Ptolemy is also mentioned as a geographical source for the name of Britain (XII.4a ⟨1⟩) and also in relation to his treatise on the astrolabe (XVIII ⟨4⟩), to point out that there is nothing in it about how to place the star pointers of the rete, from which Moses concludes that there is no adequate method for it. This treatise by Ptolemy must be a reference to the medieval treatises on the construction of astrolabes (the above mentioned as using the Hebrew construct expression *keli habaṭah* to name the astrolabe) that circulated under his name; this rather than his *Planispherium* must be the source implied in Moses' reference.[66] In the same context and with the same conclusion (there is no proper method to place the star pointers in the rete), Moses refers (XVIII ⟨5⟩) to the treatise on astrolabes "in 42 chapters of one of the great Muslim sages, in which he explained all the remaining questions" (except for this one). This reference must be to Abū al-Qāsim Aḥmad ibn al-Ṣaffār (d. 1035), who wrote a treatise on the use of astrolabes (extant in three Arabic versions) that was translated into Hebrew at least three times, first by Jacob ben Maḵir ibn Tibbon (1271–1275), then by Isaac al-Corsuno (in the second half of the 14th century), and finally by Moses ben Baruch Almosnino (1518–1579/80).[67] It is tempting to speculate why Moses decided to omit Ibn al-Ṣaffār's name when he surely knew it very well while he was writing. Was Moses' inten-

[64] Millás Vallicrosa 1959, 41–42 (Hebrew) and 47–48 (Spanish transl.). Lévy and Burnett 2006, 164–174 (English translation of 7.1–13) and 202–204 (Hebrew text of 7.1–13).

[65] As regards the value 23;51º in Ptolemy, see *Almagest*, I, 12. The value attributed to Azarquiel but found in the Toledan Tables is 23;33,30°; see Toomer 1968, 30.

[66] For Ptolemy's *Planispherium*, see Sidoli and Berggren 2007. There is a medieval Hebrew version of this text based on a Latin translation from the Arabic; see Lorch 1995, 276, n. 11. I have inspected the MS Oxford Bodleian Libraries Opp. Add. 4º 175 and there are two works attributed to Ptolemy in it: *Moftei keli ha-habaṭah* (ff. 1a–12b) and *Maʿaseh keli ha-habaṭah ha-niqra aṣṭurlab ve-hu le-Baṭalmius le-šiveʿah aqlimim* (ff. 13a–19a); they both deal with the construction of an astrolabe and Moses might be referring to either of them. I am currently working on the edition and translation of these two anonymous texts related to Ptolemy.

[67] In relation to the Hebrew versions of Ibn al-Ṣaffār, see Zonta 2011, 34; and Robinson and Melammed 2007, 19:712 (both in relation to Ben Maḵir). In relation to Ibn al-Ṣaffār's treatise, see Millás Vallicrosa 1955), 35–49 (study in Spanish) and 47–76 (edition of Ibn al-Ṣaffār's text in Arabic); Millás Vallicrosa 1931, 29–48 (Catalan translation of Ibn al-Ṣaffār's text); and Kunitzsch 1989, 48 (chapter X). Here Kunitzsch refers to the 42 chapters of the Arabic version of Ibn al-Ṣaffār edited by Millás Vallicrosa (MS San Lorenzo de El Escorial, Biblioteca del Real Monasterio 964) and the 32 chapters of the unedited longer version (MS London British Library Add. 9600, ff. 262v–280v).

tion to dim the Muslim contribution by placing it in the background and omitting the very illustrious and well known names of Muslim astronomers so that the Hebrew ones got more attention and promotion? This might explain why, in Moses' text, there is only one Arabic source quoted by name (Azarquiel, in VIII.2 ⟨1⟩).

Finally, Moses makes five self-references to books, namely chapters, of his treatise on the astrolabe,[68] which show that his text was intended to be all inclusive as regards the kinds of problems that readers could encounter in their understanding of the subject and its corresponding calculations. These are references to problems he has discussed in his text. In addition, on several occasions Moses introduces expressions that strengthen the unity and interrelation of the different sections and chapters of his text: "as we have explained" (IV.2 ⟨4⟩), "as I am going to explain in the following chapter" (IV.4 ⟨3⟩), "as we have previously said" (VI.1 ⟨7⟩), "as I have showed you" (VII.1 ⟨2⟩), "as we did before" (VIII.1 ⟨2⟩), "as we are going to explain more" (XIII.3a ⟨3⟩), "as we are going to explain" (XXIII.3 ⟨3⟩), "as we already explained" (XXIII.7 ⟨3⟩), and "do as has been explained" (XXIII.9c ⟨7⟩), among others. These self-references fulfil two main roles: to facilitate the navigation through the complete text, which Moses ben Abraham presents as all inclusive regarding problems related to astrolabe use; and to strengthen the user's feeling that the text is coherent and self-contained, and follows a clear outline, not only in the arrangement of the topics, but in the interrelation of them. This impression is bolstered with the proofs that Moses ben Abraham interspersed when dealing with certain problems and with the references to prestigous figures like Euclid, Ptolemy, Theodosius, Azarquiel, Abraham Ibn Ezra, Abraham bar Ḥiyya, etc. in certain sections of his treatise

IV. An All Inclusive Self-Contained Handbook on Astrolabe Uses for Istanbul Jews

I deal in this section with the structure of the text, its technical details, and Moses' contribution to astrolabe knowledge. Moses' treatise is a late astrolabe text in the sense that, when Moses wrote it (very likely in the first quarter of the 16th century), astrolabe texts in Hebrew language had been circulating since the mid-12th century.[69] Thus Moses seems to have collected information from previous Hebrew sources in his treatise, which is apparent in the terminology he uses (as seen in the previous section) and in the methods he collected in his exposition (that we discuss partly in this section and partly in the corresponding footnotes to the translation). Moses not only mentions his Hebrew sources by name, but he also sometimes critiques them and refutes their methods.

The arrangement of the contents of Moses ben Abraham's treatise on the uses of astrolabes is standard in comparison to earlier and contemporary Hebrew sources on the same subject. In Table 3, I have classified the distinctive uses of astrolabes in Moses' text, keep-

[68] In Chapters IV.4a ⟨2⟩ and ⟨19⟩; X.3; XII.2 ⟨5⟩; and XV.2a ⟨2⟩.

[69] In relation to the emergence of this specific literature in Hebrew language, see Rodríguez-Arribas 2014, 221–225.

ing the chapter number and describing the main content of the chapter rather than the literal title in Moses' treatise:

TABLE 3: Chapters of Moses ben Abraham's text according to the uses of astrolabes

Heavenly positions in *sphaera recta* and with respect to a local horizon	II. The position of the sun and its diametrical opposite. III. The solar altitude by daytime and nighttime. VII. The meridian altitude of the sun by daytime and nighttime. X. Meridian altitude of any fixed star. XI. Altitude of the sun using the hour. XII. Ascension of the zodiac signs on the straight and inclined horizons. XIII. Positions of the upper planets. XIV. Rising and culmination of any zodiac degree or star in the local horizon. XV. Declination of any zodiac degree or star. XVI. Culmination of any fixed star. XVII. Diurnal and nocturnal arcs of stars and planets. XVIII. Impossibility of knowing the longitude of any fixed star with an astrolabe. XIX. Latitude of the fixed stars.[70] XXIII. Shadows with a gnomon and with an astrolabe.
Horary and seasonal calculations	IV. Diurnal and nocturnal arcs and time in seasonal and equinoctial hours. VI. Telling time by nighttime. IX. Quarters of the year. XXV. Telling time when there is no plate for one's latitude. XXVI. Morning and evening twilights.
Horizontal coordinates	I. Identification of the latitude of the plate. VIII. Longitude and latitude of any inclined horizon. XX. Azimuth of the sun, stars, and planets by daytime and nighttime. XXI. Cardinal points of the local horizon and azimuth. XXII. Azimuth crossing one's zenith and the zenith of another land; the *qibla*. XXIV. Azimuth with the shadow without an astrolabe.
Astrological topics	V. The four angles of the horoscope. XXVII. The twelve astrological houses.
Land surveying	XXVIII. Measure of the three dimensions.

At first glance the most obvious feature of the structure of Moses' treatise is the author's division of its contents into 28 chapters, most of which are indicated in the manuscript in large bold script (most are also numbered in the margin with Hebrew alphanumerics by two different hands; remaining unnumbered in the margin Chapters XXII and XXIV–XXVIII). Another apparent feature is the long excursus inserted into Chapter XXIII, sections XXIII.2–XXIII.9, devoted to explaining the calculation of the shadows with a gnomon (*ʿamud*) and ratios and using two diagrams (Diagrams 1 and 2). Moses himself indicates that he inserted these sections into the original plan of his treatise: "As we have not seen yet any text on this question, we present now the question of how these shadows work

[70] In Chapter XIX Moses ben Abraham criticises Abraham Ibn Ezra's method, which is the only one he explains in the treatise, complains that Mordeḵai ben Eliezer Comtino did not clarify this problem and suggests that Moses' method ("according to our method," which he keeps to himself and so remains unknown), is the only valid one.

by a demonstrated method" (XXIII.1 ⟨6⟩) and later, "to clarify, we copy how one knows the length of the shadow, either right or inverted, of any degree of altitude" (XXIII.4a ⟨3⟩). In addition, this excursus somehow emerges from the previous Chapter XXII, which deals with azimuths, and flows into Chapter XXIV, which continues with azimuths, specifically the calculation of the azimuth using the shadow. The transition from one (that discusses calculation with shadows without astrolabes) to the other (that continues with azimuth calculations and astrolabes) is the final section in Chapter XXIII dealing with the calculation of the shadows with an astrolabe (XXIII.9–XXIII.9e). There is no disruption of style or vocabulary among these three chapters, although Moses explicitly says that he is translating or copying (ונעתק in XXIII.4a ⟨3⟩).[71] Here and throughout the treatise Moses consistently uses exclusively alphabetical numeration (Hebrew letters also represent numbers in the calculations, except for some occasions when numbers up to ten are written as words). Although alphabetic numeration can be also positional, positional numeration is never used. Terms that are used only here and neither before nor after this excursus in Moses' treatise are *maqiš* (projection) and *meitar meḥuṣah* (semichord or sine).[72] Despite the exceptional presence of these terms, a translation seems more likely, for Moses would have translated (from Arabic?) using his own familiar words for the topic, which explains the uniformity of the style with the surrounding language in the treatise.

The excursus in Chapter XXIII is an anticipation of Chapter XXVIII, which deals with the standard calculations of height, depth, and distance using the shadow square on the back of an astrolabe, while the excursus in Chapter XXIII deals with problems directly related to shadows, first without using an astrolabe and then using one. The excursus in Chapter XXIII indicates a long tradition of solving these problems (especially in the Islamic culture) with methods that do not consider the use of mathematical instruments—except for the use of a gnomon (for example, a straight wooden stick)—and were therefore cheaper and more widespread, thus what might be called "folk astronomy."[73] Trigonometrical calculations only emerge in the excursus, while ratios are present in other parts of the treatise.[74] Chapter XXIII is a challenge because of the approximation it demands from the nonprofessional astronomer to move between the geometry of the shadow square and spherical geometry, while Chapter XXVIII displays a more elementary geometry despite being the last chapter of the book. Chapters XXIII and XXVIII are the only ones with references to diagrams, which are accordingly drawn on the manuscript (original images in Diagrams 1 to 7 of the Hebrew edition); I have reproduced them with improvements (Diagrams 1 to 7

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[71] This root can mean both activities in the context of the treatise, but Moses' words do not help to clarify whether he is doing one or the other.

[72] *Maqiš* in XXIII.4a ⟨5⟩–⟨6⟩; XXIII.4b ⟨5⟩; XXIII.5a ⟨7⟩; and XXIII.6 ⟨1⟩; and *meitar meḥuṣah* in XXIII.4b ⟨2⟩ and ⟨12⟩; XXIII.5 ⟨2⟩-⟨6⟩; XXIII.6 ⟨2⟩–⟨3⟩, XXIII.5a ⟨5⟩–⟨6⟩; XXIII.5b ⟨2⟩–⟨3⟩ and ⟨5⟩; and XXIII.7 ⟨2⟩–⟨3⟩.

[73] On this long folk tradition in Muslim culture, see, for example, Varisco 1997 and 2000; Schmidl 2015; King, ⟨https://muslimheritage.com/wp-content/uploads/1799/02/davidking-sacredgeography.pdf⟩, accessed June 1st 2020; King 1999 and 1990.

[74] There are ratios (Hebrew *yaḥas* or *ʿereḵ*)—except for the excursus, which I do not mention here—in III.4 ⟨2⟩, IV.7 ⟨8⟩, VII.3 ⟨7⟩–⟨8⟩, XII.3 ⟨6⟩, XXIV ⟨4⟩ and ⟨7⟩, XXVIII.1 ⟨4⟩, ⟨10⟩, ⟨12⟩–⟨13⟩, and ⟨16⟩, XXVIII.2 ⟨4⟩–⟨5⟩, XXVIII.4 ⟨3⟩–⟨5⟩, ⟨7⟩, and ⟨9⟩–⟨11⟩, XXVIII.4a ⟨2⟩, XXVIII.5 ⟨5⟩, XXVIII.5a ⟨5⟩–⟨6⟩, XXVIII.6 ⟨3⟩–⟨4⟩, ⟨6⟩, XXVIII.6a ⟨4⟩–⟨5⟩, and XXVIII.6b ⟨5⟩ and ⟨7⟩–⟨17⟩.

of the English translation), plus an additional one (Diagram 4a) that is not in the manuscript but I have introduced to clarify Moses' related explanation.

The rest of the structure of the treatise is standard in the contents and follows the usual sequence in treatises about astrolabe use, with the exception of the demonstrations that Moses inserts here and there in relation to specific topics, namely, the calculation of the altitude of the sun, the time in seasonal hours, the meridian altitude of the sun when it is between two almucantars, the declination of any degree or star with respect to the equator, the cardinal points of the horizon by day and by night, the azimuth crossing one's zenith and the zenith of another land, the inverted and the right shadows, why shadows are equal to each other at 45º, and how the moving rete method for the division of the houses works. Moses pays special attention to the calculation of the azimuth, the *qibla*, and the four cardinal points of the horizon, all of them related to orientation to a local horizon. He must have been influenced by the Islamic environment of Ottoman Istanbul, in which religious orientation was practiced during Muslim prayers, which have to be performed facing the Kaʿba in Mecca five times every day. The calculation of the *qibla* was a religious use of astrolabes, for Muslims need to pray facing a very specific point of the local horizon, but Moses' presentation of the topic gives a non-religious turn to most of these calculations, so that it becomes an astronomical/geographical question related exclusively to orientation and so relevant for anybody regardless of religious background. Moses mentions the *qibla* (אלקבלא) only twice (in Chapters XXII.1 ⟨1⟩ and XXII.4 ⟨1⟩), preferring other terms to denote orientation and direction, such as different Hebrew variations of the Arabic loan word for azimuth (*samut*, *samt*, *sumt*, *simt* in Chapters XX–XXII), and straight alignment or direction (*noḵaḥut* in Chapter XXII.4 ⟨4⟩).

Contrary to other texts (notably Abraham Ibn Ezra, who devoted several sections of his treatise to different astrological calculations) Moses' text has only one astrological chapter,[75] the calculation of the astrological houses, and a section of a previous chapter (V), where he explained how to find the four cardines or angles (first, seventh, fourth, and tenth houses). Moses explains the division of the ecliptic into houses by two methods, the most usual ones, both using the hour line divisions engraved on many astrolabes. The fixed rete method uses the hour lines divisions of the astrolabe and a thread and keeps the rete fixed during the calculation (XXVII.3–XXVII.3b), while the moving rete method uses the same hour divisions but moves the rete in specific ways (XXVII.2). What is new and distinctive in Moses' presentation in relation to other Hebrew texts on this specific topic (for instance, Ṭaiṭaṣaq's explanation of the houses) is that Moses provides a demonstration (XXVII.3c) of how the moving rete method works and why the houses that are in the eastern quadrants,

[75] Abraham Ibn Ezra devoted much attention to astrological calculations in the first version (division of the houses and aspects), second version (the revolution of the sun, the division of the houses, aspects, and directions), and third version (the division of the houses, the solar revolution, aspects, and directions) of his astrolabe text. In relation to the astrological contents in Ibn Ezra's treatises on the astrolabe in Hebrew and Latin, see Rodríguez-Arribas 2014, 228–230 (first Hebrew version), 233–235 (second Hebrew version), 239–240 (third Hebrew version), and 253–254 and 257–258 (Latin version). The absence in Moses' text of any mention of astrological aspects, directions, or the revolution of the years and nativities, all essential astrological calculations, might be due to the fact that most of these calculations relied on the positions of the planets and these can only be known accurately by the use of tables.

above and below the horizon, are found by moving the ascendant through two hours, while the western ones, above and below the horizon, are found by moving the descendant through two hours. As Moses provides an explanation for the moving rete method (not for the fixed rete method) and says in addition that "for this reason, the division of the houses as done above is right according to the requirement of the art, i.e., the art of the astrological judgements" (XXVII.3c ⟨15⟩), it seems that Moses favored the moving rete method, contrary to his contemporary Joseph ben Solomon Ṭaiṭaṣaq, who was associated with the fixed rete method,[76] the only method that Ibn Ezra also refers to in the three Hebrew versions of his astrolabe text.

One of the most distinctive contributions of Moses' text in Hebrew literature about astrolabes is that he provides geometric demonstrations (*mofetim*), explanations (*sibbot*), and reasons/logic foundations (*ṭeʿamim*) to confirm the correctness of the calculations he is explaining and to make how and why they work more understandable. This is an unusual feature in Hebrew astrolabe texts, which are characteristic for their too practical and very summary approach. Moses' treatise might have been a teaching handbook, a text to use with students in the context of the yeshivah or in private scholarly meetings. This can be concluded from several features: (1) the use of diagrams to illustrate the written explanations; (2) the presence of several practical examples and demonstrations of them, all supported by diagrams (Diagrams 1, 2, 5, and 6);[77] (3) the presence of definitions or quasi-definitions (i.e., descriptions);[78] (4) alternative methods that can prompt additional discussions and explanations in a teaching class context;[79] (5) "what to do" situations to solve the shortcomings of the instrument or the specific circumstances of the calculation;[80] and, fi-

[76] Rodríguez-Arribas and Kozodoy 2020, 92–96 (the fixed rete method) and 94 (mention of Ṭaiṭaṣaq in relation to this method).

[77] In XXIII.4b (how the shadow works) and XXIII.5 (the correlation of the solar altitude and the shadow) and XXIII.5a (its demonstration) as well; in XXVIII.5a (example with the geometry of the measure of the depth of a well with the shadow square of an astrolabe), and XXVIII.6a (example with the geometry of the measure of the width of a river with the shadow square of an astrolabe).

[78] Almucantar (I.1 ⟨4⟩), the degree of the sun (II.1 ⟨1⟩), the diametrical opposite of the sun (II.1 ⟨2⟩), the edge of the alidade (II.2 ⟨3⟩), the altitude of the sun (III.1 ⟨1⟩), the almuri or beginning of Capricorn in the rete (IV.3 ⟨8⟩), almucantar (IV.4a ⟨7⟩), meridian altitude of the sun by daytime and by nighttime (VII.1 ⟨1⟩), latitude of a place (VIII.1 ⟨1⟩), the longitude of a place (VIII.6 ⟨1⟩), the diurnal and nocturnal arcs (XVII.1), the four quadrants of the horizon (XX.1), the *qibla* (XXII.1 ⟨2⟩), straight (XXIII.1 ⟨3⟩) and inverted shadows (XXIII.1 ⟨4⟩), description of the shadow square on an astrolabe (XXIII.9a), evening twilight (XXVI ⟨1⟩–⟨2⟩) and morning twilight (XXVI ⟨6⟩), and angles or cardines of a horoscope (XXVII.1).

[79] Two methods to identify the latitude of the latitude plate (I.1 and I.3), two methods to calculate the position of the sun (II.2 and IX.1), two methods to find the days of the year when the daytime starts to increase or to diminish (II.4 ⟨5⟩ and II.4 ⟨6⟩), three methods to calculate the diametrical opposite of the sun (II.5, II.6, and II.7), two methods to tell time in seasonal hours (IV.3 and IV.4), two methods to find the meridian altitude of the sun with an instrument that is not complete (VII.3 and VII.4), two methods to find the latitude of a place when the sun is neither at the solstices nor the equinoxes (VIII.4 and VIII.5), three methods to find the position of the upper planets (XIII.1, XIII.2, and XIII.3), two methods to divide the ecliptic into the eight houses that are not the angles (XXVII.2 and XXVII.3), and two methods to measure the height of an object whose basis is not accessible for the observation (XXVIII.4 and XXVIII.4a). Different or alternative methods mean sometimes just a different way of performing the corresponding calculation.

[80] If one is finding the position of the sun and the astrolabe does not have a calendar scale (II.3); if one is taking the altitude of the sun but the day is cloudy (III.3 ⟨2⟩); if one is telling time by daytime in seasonal hours but there are no seasonal hour divisions engraved on the latitude plate (IV.7); if one is telling time by nighttime in seasonal hours but there are no seasonal hour divisions engraved on the latitude plate (VI.3); if one is calculat-

nally, (6) the presence of theoretical tools, demonstrations, and proofs that help to understand how and why the calculations work.[81] All these features make Moses' text one of the best among the Hebrew sources I am aware of that are suitable to be used in a class of applied astronomy and this might be the intention of its author.

A text like this might have found its place in a Sephardic curriculum where philosophy and science were easily accommodated side by side with religious studies, and even considered necessary for an accurate understanding of them. The Sephardic curriculum might have already been implemented by the time Moses' family settled in Istanbul (in Ottoman hands since 1453 and with a continuous although uneven arrival of Sephardic immigrants since 1391). Alternatively, he might have been one of those Sephardic immigrants who contributed to its implementation and lived in Istanbul—like Gedaliah ibn Yaḥya (d. 1488), Ḥanokh Saporta of Catalunya (who moved to Istanbul c. 1481, was very much interested in philosophy, and taught Comtino) and Shabbetai ben Malkiel ha-Cohen (with whom Comtino polemized about Ibn Ezra's opinions)—or in Salonika—like Joseph ben Salomon Ṭaiṭaṣaq (author of an astrolabe treatise), Solomon ben Jacob Almoli (d. 1542, physician and encyclopedic author), and Eliyahu ben Abraham (physician and author of a treatise on the bubonic plague).[82] The chief rabbis of the Jewish community in Istanbul continued to

ing the meridian altitude of the sun but the astrolabe is not complete (VII.3); if one is placing the sun among the almucantars according to its altitude but the astrolabe does not have a specific almucantar for this specific altitude (IX.5 with a practical example); if one is finding the ascension of a sign in an inclined horizon but there is no latitude plate for one's horizon (XII.3); and if one is calculating the height of an object and its basis is not accessible for the observation with the astrolabe (XXVIII.4 ⟨1⟩–⟨7⟩ with practical example in XXVIII.4 ⟨8⟩–⟨24⟩ by method one and by method two in XXVIII.4a).

[81] Theodosius' proposition explaining that two great circles of the sphere bisect one another (II.7 ⟨3⟩–⟨5⟩); why the calculation of the altitude of the stars works with an astrolabe (III.4 ⟨1⟩–⟨13⟩); the calculation of the seasonal hours using the altitude of the sun, which moves in circles parallel to the equator that are intersected by the almucantars, which are circles parallel to the horizon; the circles of the hour above and below the horizon are also intersected by the circles parallel to the equator (IV.4a ⟨1⟩–⟨26⟩); that the arc of the circle parallel to the equator that the sun circumvolves and the limb of the astrolabe are similar (IV.5 ⟨9⟩); telling time during nighttime (VI.2 ⟨1⟩–⟨2⟩); how the meridian altitude during daytime and during nighttime relate to the motion of the sun in the rete of the astrolabe (VII.3a); why the solar altitude at noon at the equinoxes is subtracted from 90 to get the local latitude (VIII.1 ⟨5⟩); why the solar declination is subtracted from 90 and the solar altitude of the sun at noon at the winter solstice is subtracted from the result of this difference to get the local latitude (VIII.2 ⟨3⟩); why the solar declination is added to 90 and the solar altitude of the sun at noon at the summer solstice is subtracted from the result of this difference to get the local latitude (VIII.3 ⟨2⟩–⟨8⟩); how the fact that almucantars intersect the circles parallel to the equator relates to the calculation of the declination of a fixed star on the straight horizon (XV.2a ⟨2⟩); demonstration of the calculation of the four cardinal points of the horizon and the azimuth (XXI.2b); demonstration of why the calculation of the quadrant of the azimuth using the meridian, zenith, and the circles parallel to the equator works (XXII.2a); demonstration with a diagram (XXIII.4b), ratios, and trigonometry of why the right and the inverted shadow calculations work (XXIII.4a–4b); demonstration of the moving rete method using the circles parallel to the equator and how the diurnal hours relate to the ascendant while the nocturnal ones relate to the descendant (XXVII.3c); and the proof of why a method of calculating is the correct one (XXVIII.6b ⟨9⟩–⟨19⟩).

[82] See Shefer-Mossensohn 2015, 117–119. For the education of Sephardic Jews in Ottoman lands, see Lehmann 2005, 29–30; and Ben-Naeh 2008, 257–261 (which also includes notes about the 16th century). Rozen says about this cultural activity that "most of this activity did not in any way touch the average Jew in Istanbul, so there was a rather vast arena for scholars to engage freely in any topic of study they thought interesting until they were confronted by some practical consideration," and "the immigration and settlement of Iberian scholars created new study groups which continued the scholarly tradition of Spain. But most of them were destitute; they had lost not only their earthly belongings, including precious books and manuscripts, but often their families as well. This combination of physical and emotional hardship among the Iberian scholars, plus the lack of

be Romaniot (Greek) Jews during this early period, and were also much engaged in the study of science and philosophy (though these were considered to be of a more inferior nature than religious studies): Moses Capsali since the 1450's (who was also the administrative head of the Jewish community and came from a strong German-Ashkenazi educational background) and Eliyahu ben Abraham Mizraḥi (very interested in mathematics and astronomy and disciple of Comtino) since the end of the 15th century (with Shealtiel, a Sephardic immigrant, as the fiscal and administrative head of the Jews).[83] The fact is that both groups, Romaniot and Sephardic scholars, were involved in secular studies in Istanbul and Salonika during this period, although there were frequent reactions against "Greek wisdom" arising from religious scruples. Sephardic Jews also introduced Hebrew printing in Istanbul (1504): the brothers David and Samuel Naḥmias who were already printers in Spain (Híjar?) before migrating to Ottoman lands. However, most philosophical and scientific books kept circulating during the 16th century only in manuscript form (like Ibn Ezra's, Comtino's, Ṭaiṭaṣaq's, or Moses' astrolabe treatises), books published in other languages than Hebrew, and oral teaching.[84]

V. Conclusion: Moses ben Abraham de Çivdat—A Figure of Continuity

Moses ben Abraham de Çivdat is, in the history of science and in the more general field of the intellectual activities of premodern Jews, a figure who typifies the continuity and the adaptation that characterize knowledge in motion (of people, texts, and tools) and its transfer among cultures in the Mediterranean basin. Moses embodies in his technical text the culture of the Jews who lived in Castille under Christian rule and the Romaniot Jewish culture that flourished in Ottoman lands under Muslim rulers. The presence of Iberian Jews in Ottoman lands since the persecutions of 1391, and above all since the expulsion of 1492 and its aftermath, created a bridge between Jewish Iberian and Jewish Ottoman cultures, and one of its stones was Moses ben Abraham's treatise on the astrolabe.

Moses' treatise exemplifies the diffuse relationship of local practices with transcultural and transreligious scientific endeavours, and proves how the continuity between periods and localitites in regard to scientific activities frequently relies on isolated (too often underrated or ignored) figures like Moses ben Abraham de Çivdat. Moses clearly combines the best of two worlds in the terminology and sources of his book: astrolabes texts written by Iberian Jews in their European diaspora (Abraham Ibn Ezra) and texts from Byzantine (Romaniot) Jews written in pre-Ottoman Constantinople and Ottoman Istanbul (Mordeḵai

books, had a substantial adverse effect on rabbinical studies and on education of the younger generation of immigrants"; see Rozen 2010, 248 and 260, respectively, and 259–260 (list of Sephardic scholars moving to Istanbul from Iberian Peninsula). For astronomical activity and the use and construction of astronomical instruments in the Ottoman lands, see Shefer-Mossensohn 2015, 46–56.

[83] Eliyahu Mizraḥi wrote a *Sefer ha-Mispar* on arithmetic and commentaries on Euclid's *Elements*, Ptolemy's *Almagest*, and the Persian tables (the first is found in manuscript and in a 16th-century printed version but the other two remain in manuscript); see Hacker 2007.

[84] See Rozen 2010, 244–277. Only certain uncontroversial works reconciling faith and philosophy were printed; see Rozen 2010, 253–255.

Comtino), as well as different Greek and Arabic mathematical sources circulating in the Mediterranean. Moses' text shows how easily technical knowledge—here applied astronomy based in individual performance and experience (Hebrew *melaḵah*)—circulated in the Mediterranean lands, not only in the form of books but in the form of individual persons. Thus the written text (when there is one) is merely the mute witness of a lively and vibrant cultural exchange whose details are lost perhaps forever, or only glimpsed out of the corner of the researcher's eye. Moses' treatise—extant in one manuscript and with no apparent further influence in later sources—is the occasion of a microsocial study of the role of "textual objects," objects described in texts, to understand not only actual physical objects (e.g. astrolabes made and/or used by Jews) but how knowledge moves, adapts, and continues by means of isolated figures that bridged the gap between lands, languages, and religious cultures and so creates the intellectual contexts that make possible new approaches and new findings.

VI. Hebrew Diplomatic Edition of Moses ben Abraham's *Explanation of the Astrolabe with Clear Explanations* in MS Paris BnF heb. 1030, ff. 45b–71a (unique) with the English Translation of it

General notes on the edition:

- The main purpose of the edition of a manuscript is to establish what the original author meant to say and this is certainly one of my purposes. However, as this is a non-autograph unique manuscript, the editor also considers in the edition the mistakes and hesitations of the copyist as well as the interventions of the different users of the manuscript and its contents. All these interventions constitute the history of the manuscript and its reception and are an essential part of it, especially because this text and its author were unknown until my study. Thus, the mistakes of the copyist have been indicated and corrected in footnotes. Later additions by readers and users of the manuscript (reading marks, marginal and interlineal additions, and comments) have been analyzed and indicated in footnotes. A few marginal and interlineal additions have been integrated into the body text of the edition only when they improve the intended meaning and its understanding; their inclusion is always indicated in footnotes and in the text (see the notes on sigla below). Whether they are included or not, I comment in footnotes on the correctness of the additions and notes of the different users (differentiated by their scripts and marks).
- The copyist (and possibly Moses ben Abraham) used two types of punctuation marks in the text: colon and period, both placed high in the line as it was usual in the medieval and early modern scripts. I have respected this punctuation most of the time, but in their equivalent modern forms, and have enlarged it to facilitate the intended meaning and to agree with the standards of English syntax.
- The different hands referred to in the footnotes do not mean always different writers, but rather different interventions of the users of the manuscript, who many times are clearly different readers, but not always.

Notes on sigla in the diplomatic edition:

- I have used [ ] for interlineal and marginal notes in the manuscript that I have introduced into the text and { } to indicate words that have to be removed from the text because they are wrong (whether they are indicated or not as such in the manuscript).
- Errors in the Hebrew text have been noted and corrected in the footnotes of the edition and in the text of the translation.
- I have used < > to indicate letters that I have added in my transcription to make sense of the Hebrew text, to complete any abbreviated form in the manuscript, and to introduce a word necessary to complete the meaning.

- The manuscript presents several letters and words that have been crossed out, I reproduce them in the form ~~xxx~~ indicating in a footnote whether the crossing out is right according to the meaning intended.
- The initial words of the chapters and the initial word of some sections and sentences are written in the manuscript either with larger bold letters or with just larger letters, I have reproduced these differences of size and bold script in my edition.
- I have introduced punctuation where necessary and have divided the chapters of the Hebrew text of the manuscript (that I indicate with Roman numbers) into sections and sentences, which I have numbered with Indo-Arabic numerals. The folio number of the MS is indicated between ( ).
- Moses ben Abraham's text contains seven diagrams; I have reproduced them in the edition and corrected them when it was necessary (indicating my correction) in the translation.

<u>Notes on sigla in the English translation</u>:

- I have used [ ] for explanatory words introduced in the translation and to indicate corrections.
- I have used 〈 〉 to indicate words that I have added in my translation to make sense of the Hebrew text, as well as sentences in the sub-sections of the Table of the contents that are not in the manuscript.
- The folio number of the MS is indicated between ( ).
- I have introduced punctuation where necessary and have divided the chapters of the text (which I indicate with Roman numbers) into sections and sentences, which I have numbered with Indo-Arabic numerals. Numbers of the sections and sentences are also between 〈 〉 because they are not in the MS.
- Moses ben Abraham's text contains seven diagrams; I have reproduced them and corrected them when it was necessary (indicating my correction) in the translation. I have placed them in the corresponding section according to the contents, always keeping them on their respective folio on the MS.

<u>Table of the contents:</u>

VII (52a) **Chapter: To know the solar altitude at noon for any day that you want and the degree of the sun at midnight**

⟨VII.1 The maximum altitude of the sun on the meridian by day⟩

⟨VII.2 The maximum altitude of the sun on the meridian by night⟩

⟨VII.3 What to do when the instrument is not complete and the degree of the sun falls between two almucantars: Method one⟩

⟨VII.3a Demonstration of method one⟩

⟨VII.4 Method two⟩

VIII Chapter: To know the latitude and longitude of any place

⟨VIII.1 The latitude for any oblique horizon with the meridian altitude of the sun at the equinoxes⟩

⟨VIII.2 The latitude when the sun is at the winter solstice⟩

⟨VIII.3 The latitude when the sun is at the summer solstice⟩

⟨VIII.4 The latitude when the sun is in any other degree of the zodiac: Method one⟩

⟨VIII.5 The latitude when the sun is in any other degree of the zodiac: Method two⟩

⟨VIII.6 How⟩ to calculate the longitude of ⟨one's⟩ location ⟨using lunar eclipses and an astrolabe⟩

⟨VIII.7 How to find the longitude using the conjunction of the moon or a planet with one of the fixed stars⟩

⟨VIII.8 The latitude using the fixed stars⟩

⟨VIII.8a The latitude using a fixed star that rises or sets on the horizon⟩

⟨VIII.8b The latitude using a fixed star that has no declination with respect to the equator⟩

IX Chapter: To know for any day the position of the sun in the zodiac by another method [method one]

⟨IX.1 The position of the sun in the zodiac by method one⟩

⟨IX.2 The path of the sun in the zodiac and the four quarters of the year⟩

⟨IX.3 Using the quarters to place the position of the sun among the almucantars⟩

⟨IX.4 Relevance of the knowledge of the right quarter of the year to localizing the sun⟩

⟨IX.5 What to do when the instrument does not have an almucantar for the altitude of the sun⟩

X Chapter: To know the altitude of any ⟨fixed⟩ star in the midheaven, ⟨that is⟩ when it is on the meridian

XI Chapter: To know the altitude of the sun using the knowledge of the hour and the position of the sun

XII Chapter: To know the ascension of the zodiac on the right and on the oblique horizons

⟨XII.1 The ascension of any zodiac sign in the *sphaera recta*⟩
⟨XII.2 The ascension of any zodiac sign in any oblique horizon⟩
⟨XII.3 What to do when there is no plate for one's latitude⟩

XIII Chapter: To know the positions of the planets

⟨XIII.1 Method one: When any of the superior planets or the moon is rising⟩
⟨XIII.2 Method two: When any of the superior planets is setting⟩
⟨XIII.3 Method three: When any of the superior planets is on the meridian⟩
⟨XIII.3a Conditions under which method three is the most accurate⟩
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(45b) The distinguished sage Rabbi Moses de Çivdat—may his Rock and Redeemer protect him—the son of Abraham de Çivdat, composed an explanation of the astrolabe with clear explanations.

I CHAPTER ON THE IDENTIFICATION OF THE LATITUDE OF THE PLATE[1]

⟨I.1 Method one: The almucantars below the east-west line⟩

⟨1⟩ Count all the almucantars placed below the east-west line. ⟨2⟩ If the astrolabe is complete, the number of the almucantars is the latitude of the place.[2] ⟨3⟩ If the astrolabe is medial, multiply the almucantars by two; if it is tertial, multiply them by three; and so on.[3] ⟨4⟩ The reason of this is that the centre[4] of the astrolabe represents the northern pole. ⟨5⟩ The latitude of the place is the distance of the pole of that specific local horizon from the equator; its value is the altitude of the northern pole of ⟨that⟩ horizon.

⟨I.2 Explanation about the almucantars⟩

⟨1⟩ The almucantars separate and rise above the horizon ⟨single⟩ degree by ⟨single⟩ degree if the instrument is complete, or every two degrees if the instrument is medial, and so on.[5] ⟨2⟩ The almucantar that crosses the northern pole is the limit of the altitude of the pole of that ⟨local⟩ horizon.[6] ⟨3⟩ When one knows how many almucantars there are from the horizon to the pole, if the instrument is complete, one knows that their number is the number of the degrees of the altitude of the pole. ⟨4⟩ If the instrument is medial, one multiplies [this number] by two, and so on.[7]

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[1] Marginal note: "The meaning of the latitude plate is knowing which of the plates of the astrolabe is the one corresponding to the latitude of a specific location so that it represents the horizon of th⟨is specific⟩ place." This is necessary when the latitude is not engraved on the plate of the astrolabe and must be calculated by counting the almucantars.

[2] A complete astrolabe is an astrolabe with latitude plates that have almucantars for every degree of altitude; an incomplete astrolabe is one that does not display an almucantar line for very degree, but for every two, three, and so on.

[3] Abraham Ibn Ezra's treatises explaining the uses of astrolabes already refer to astrolabes with different numbers of almucantar divisions displayed on the latitude plates; see MS Paris BnF heb. 1045, f. 189a (second version), and MS Moscow Russian State Library Günzburg 937, f. 3b (third version). Jacob ben Maḵir ibn Tibbon's Hebrew translation of Ibn al-Ṣaffār's treatise on the astrolabe also refers to this classification of astrolabes according to the number of the almucantar lines; see MS Jerusalem NLI Heb. 3573, f. 2b. I am using these manuscripts (which are not necessarily the best versions available, but are correct and complete for the sections I quote) because they were all copied in the 15th century and display Byzantine (two) and Sephardic (one) scripts and thus refer to the time and the geographical areas of Moses ben Abraham's itinerary: MS Paris BnF heb. 1053 (Byzantine), MS Paris BnF heb. 1045 (Sephardic), and MS Günzburg 937 (Byzantine, 1453). Abraham Ibn Ezra's versions of his astrolabe text are extant in more than 50 manuscripts.

[4] This word is also used in Mordeḵai Comtino's treatise on the northern astrolabe; see MS Paris BnF heb. 1095 (copied in the 15th century, Byzantine script), f. 125b (טבור הכלי).

[5] Every three degrees if the instrument is tertial, or every five degrees if it is quintile, etc.

[6] The altitude or height of the pole is the arc between the northern pole, which is the axis of the daily motion, and the local horizon. This is Abraham bar Ḥiyya's definition of this concept in his *Sefer ḥešbon*, see Millás Vallicrosa 1959, 40 (Spanish) and 31 (Hebrew).

[7] One multiplies the number of the almucantars between the horizon and the pole by three if the instrument is tertial, or by five if it is quintile, and so on.

(45b) פירוש לכלי האצטרולב בסבותיו המוחשות חברו החכם כבוד ר<בי> משה דסיבדאת י<שמרהו> צ<ורו> ו<גואלו> ב<ן> ר<בי> אברהם דסיבדאת.

<I> **שער**[1] **בידיעת** הכרת לוח הארץ.[2]

<1.> <1> תמנה כל הגשרים היורדות למטה מהקו ההולך ממזרח למערב. <2> ואם הכלי שלם הנה כמספר[3] הגשרי<ם> הוא מרחב הארץ. <3> ואם הוא חצי ערוך הגשרים בשנים ואם הוא שליש ערוך אותם בשלשה וזולת זה. <4> וסבת זה כי להיות טבור {~~הארץ~~}[4] הכלי כדמות[5] הקטב הצפוני. <5> והיה מרחב הארץ המרחק שמקוטב {~~הארץ~~}[6] האופק הדרוש מעגולת השווי, ובשעורו יגבה הקוטב הצפוני על האופק.

<2.> <1> והיו הגשרים הם אשר ירחקו ויגבהו מעל האופק אם מעלה מעלה אם הכלי שלם או מב' מעלות אם הכלי חצי וזולת זה. <2> הנה הגשר העובר על הקוטב הצפוני הוא אשר בו תכלית גובה הקוטב מן האופק. <3> וכאשר נדע כמה גשרים מהאופק עד הקוטב נדע שבשעורם הוא מעלות גובה הקוטב אם הכלי שלם, <4> או נכפלם אם הכלי חצי וזולת זה.

[1] Marginal note, hand one: 'א.
[2] Marginal note, hand one: והכונה הנה בלוח הארץ הוא שנדע איזה לוח מלוחות הכלי הוא לוח ארץ פלני<ת> שיש בו אופק אותו המקום.
[3] Written במספר.
[4] Crossed out (rightly).
[5] Written בדמות.
[6] Crossed out (rightly).

⟨I.3 Method two: The almucantars between the local zenith and the east-west line⟩

⟨1⟩ One can also know this [the distance] from the equator ⟨if⟩ one counts how many almucantars there are between the point of the zenith, which is the centre of the smallest almucantar, and the almucantar where the circle of the equator meets the upper meridian. ⟨2⟩ If the instrument is complete, it itself [the number of the almucantars] is (46a) the value of the latitude. ⟨3⟩ If the instrument is medial, the value of the latitude is twice it [this number], and so on.[1]

II CHAPTER: ON THE CALCULATION OF THE DEGREE OF THE SUN IN THE ZODIAC AND ITS DIAMETRICAL OPPOSITE FOR ANY DAY

⟨II.1 Definitions: The position of the sun and its diametrical opposite⟩

⟨1⟩ The meaning of the degree of the sun is the knowledge of which degree of the zodiac is the position of the sun for any day of any of the Christian months in order to place the sun on the same degree of the zodiac ⟨on the astrolabe⟩. ⟨2⟩ The meaning of the diametrical opposite of the sun is the degree ⟨of the zodiac⟩ placed diametrically opposite to the degree of the sun.[2]

⟨II.2 Method two for the position of the sun: The calendar scale⟩

⟨1⟩ As regards the ⟨zodiac⟩ degree of the sun, this is found [*lit.* explained] by two methods. ⟨2⟩ We shall explain ⟨later⟩ the first ⟨method⟩ with God's help.[3] ⟨3⟩ The second method consists in placing the edge of the alidade, i.e., the edge that longitudinally crosses the centre of the instrument, on the day of the month we want among the days engraved on the back of the mater of the instrument, if they are engraved on that ⟨specific⟩ instrument. ⟨4⟩ Then the alidade clearly shows you on which zodiac sign and on which degree it [the position of the sun] has fallen.[4]

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[1] In the first and the third versions of his astrolabe text Abraham Ibn Ezra provided four methods to calculate the latitude (i.e., the distance from the equator) of any latitude plate when there is no indication of it on the instrument: (1) multiplying the number of the almucantar divisions below the east-west line by the caliber of the astrolabe; (2) adding 24º to the altitude of the beginning [Tropic] of Capricorn on the local horizon and then subtracting the total from 90º; (3) subtracting from 90º the altitude of the vernal equinox, i.e., the meridian altitude of the sun at the beginning of Aries or Libra [the equinoxes] on the local horizon; and (4) subtracting 24º from the altitude of the beginning [Tropic] of Cancer on the local horizon and then subtracting the result from 90º; see MS Paris BnF heb. 1053, ff. 4b–5a (first version) and MS Günzburg 937, ff. 4a–4b (third version). The second version only refers to methods (1) and (2); see MS Paris BnF heb. 1045, ff. 189a. Moses ben Abraham's second method is not in any of Abraham Ibn Ezra's texts, but is found in Eliyahu Cohen de Montalto's treatise on the astrolabe (15th century, not to be confused with Eliyahu Montalto or de Montalto, the physician of Maria de Medici and her son Louis XIII); see MS Paris BnF heb. 1047 (copied in the 15th century, Byzantine script), f. 87b.

[2] Diametrical opposite means exactly 180 degrees around the zodiac.

[3] See Chapter IX.

[4] All three versions of Abraham Ibn Ezra's astrolabe text describe this calculation; see MSS Paris BnF heb. 1053, f. 7a (first version), BnF heb. 1045, f. 188b (second version), and Günzburg 937, ff. 3a–3b (third version). All three versions underscore the inaccuracy of these divisions because of the lack of an accurate correspondence between the 360 divisions of the zodiac sphere and the 365 divisions of the calendar scale. However, Abraham Ibn Ezra's third version provides a detailed description of the calendar scales that could assist in drawing them on an additional surface although there is no explicit mention of it; see MS Günzburg 937, f. 3a (also with an eccentric calendar just as Moses in II.3, 4). See below, Appendix 5. The first version also suggests the solution but very tersely; see MS Paris BnF heb. 1053, ff. 7a–7b.

<.3> <1> עוד יודע זה מעגולת השווי והוא שנמנה כמה גשרים מנקודת נכח הראש שהוא מרכז הגש[ר][1] הקטן עד הגשר שימשש עגולת השווי מצד נקודת חצי השמים. <2> ואם הכלי שלם הוא בעצמו (46a) שעור המרחב. <3> ואם הוא חצי הנה שעור המרחב הוא כפלו וזולת זה.

<II> **שער**[2] **לדעת מעלת** *השמש* בכל יום בגלגל המזלות ולדעת נכח *השמש*.

<.1> <1> אמנם הכונה הנה במעלת השמש הוא שנדע השמש בחדש מחדשי הנוצרים וביום שנרצה באי זה מזל הוא ובכמה מעלות מהמזל הוא עד שנשים השמש בגלגל המזלות באותה המעלה. <2> והכונה בנכח השמש רצו<ני> המעלה שהיא כנגד מעלת השמש.

<.2> <1> אמנם מעלת השמש זה יתבאר בב' דרכים. <2> האחת נבארה אנחנו במה שיבוא ב<עזרת> ה<שם>. <3> אמנם הדרך השנית הוא שנשים קצה הבריח רצו<ני> קצה הבריח העובר על יושרו במרכז הכלי ונשימהו על היום מן החדש שנרצה על יום מן הימים שהם רשומים באחורי אם[3] הכלי אם היו רשומים בכלי ההוא. <4> ואז יראך יושר הבריח על איזה מזל הוא ועל כמה מעלות ממנו נפל.

[1] Interlineal correction, hand two: the original final letter (ם) is crossed out (rightly) and ר has been written above the line.
[2] Marginal note, hand one: 'ב.
[3] Interlineal addition, hand two added the punctuation of vowel *ṣere* below the alef.

⟨II.3 What to do if the astrolabe does not have a calendar scale⟩

⟨1⟩ However,[1] if the instrument does not have the Christian months engraved on it, you draw a circle on another [*lit.* a] place and divide ⟨it⟩ into 360 degrees. ⟨2⟩ Then you divide the 360 degrees into 12 ⟨equal⟩ parts and give 30 degrees to each. ⟨3⟩ You write on them the 12 zodiac signs. ⟨4⟩ After that, you draw another circle—smaller—inside the previous circle with a centre different from its centre but close to it; it represents the eccentric circle of the sun.

⟨5⟩ Then you make one straight ruler with the edge flattened and place it on the centre of the circle ⟨of the zodiac⟩, so that its end point crosses the 20th degree of the sign Pisces. ⟨6⟩ You mark with a point where the ruler intersects the small circle ⟨of the calendar⟩ that you did not engrave. ⟨7⟩ You start from here the division of the ⟨small⟩ circle into 12 parts. ⟨8⟩ After that, you start to write from this point (46b) in the section of the 12 divisions that corresponds to the month of March. ⟨9⟩ The twelve months are all placed in the twelve divisions after this [the initial point of March] according to ⟨their⟩ order. ⟨10⟩ Then you divide each of the divisions of the ⟨inner⟩ circle ⟨you drew⟩ into the number of days that correspond to the month written above it. ⟨11⟩ We have placed the month of March so that it starts from the 20th degree of Pisces, for in our time the sun enters the beginning of Aries on the [10th][2] day of March according to the computus. ⟨12⟩ You write it [the beginning of March] according to what corresponds in your time.

⟨13⟩ After that, if you want to know the degree of the sun, place the ruler on the centre and on the day you want among the days written on the circle. ⟨14⟩ The ruler directly shows you the degree of the zodiac sign that you are looking for, and this is enough.[3]

[1] Marginal note: "⟨From here⟩ until the end of this chapter it is an addition ⟨that⟩ is not in the author's version."

[2] "10th" is my correction of "20th," written in the manuscript. It should be "the 10th day" according to what Moses ben Abraham says in Chapters IX.2 ⟨1⟩ and ⟨7⟩, and IX.3 ⟨3⟩.

[3] This section (a sort of construction section inserted in a text on uses) explains that if the astrolabe does not have a calendar scale engraved on the back, it is feasible to fabricate a calendar scale on another surface and superimpose it on the back of the astrolabe to use the whole in the standard way. It could also be that one keeps this diagram separate, on the side, and consult it separately when a correspondence is needed. "This is enough," which closes the sentence here and indicates that there is not more to say about the subject or that Moses is not willing to do it, is a distinctive expression of Moses' style. This expression, with minor variants (ודי בזה, ודי זה, ודי בו, and וזולת זה, once the two first and the last and six times the third one), is found throughout the treatise, especially where the author wants to abandon a subject because the topic has been sufficiently explained. For this expression in the treatise, see Chapters II.3 ⟨15⟩; II.4 ⟨6⟩; IV.5 ⟨10⟩; IV.7 ⟨16⟩; V.2 ⟨4⟩; VII.3a ⟨8⟩; VIII.8b ⟨6⟩; XXIII.8 ⟨4⟩; and XXV ⟨12⟩.

<3.> <1> אמנם[1] אם אין לכלי חדשי הנוצרים רשומים בו תעגל עגולה אחת במקום אחד ותחלקם לש"ס מעלות. <2> עוד אחר כך תחלק הש"ס לי"ב חלקים והוא שתתן לכל חלק ל' מעלות. <3> עוד תכתו<ב> עליהם הי"ב מעלות[2]. <4> עוד אחר כך תוך אותה העגולה על זולת מרכזה אלא במרכז קרוב[3] למרכזה תעגל עגולה אחרת קטנה ממנה שהיא במקום גלגל יוצא המרכז של השמש.

<5> אחר כך תעשה מעצר אחד ישר בתכלית היושר ושימהו על מרכז העגולה עד שיעבור יושרו על מעלת העשרים ממזל דגים, <6> ועל המקום שיחתוך המעצר בעגולה הקטנה הבלתי נרשמת תרשום עליו נקודה, <7> וממנה תתחיל ותחלק העגולה לי"ב חלקים. <8> אחר כך תתחיל מהנקודה הזאת ותכתו<ב> (46b) בחלק שבצדה מהי"ב חלקים מחדש מרטי, <9> ואחריו כל החדשים הי"ב בסדר בי"ב החלקים. <10> ואחר כך תחלק כל חלק מחלקי העגולה כמספר הימים שבחדש הכתו<ב> עליו. <11> אמנם שמנו חדש מרטי מתחיל מכ' לדגים מפני שבזמנינו זה יכנס השמש[4] בראש טלה בכ'[5] יום למרטי כפי החשבון, <12> וכפי מה שיהיה בזמן שאתה בו כך תכתוב אותו.

<13> ואחר כך אם רצית לדעת מעלת השמש[6] שים המעצר על המרכז ועל היום שרצית מהימים הרשומים בעגולה, <14> והמעצר יראה לך על יושרו המעלה מהמזל שאתה מבקש ודי בזה.

[1] Marginal note, hand three: והנה עד סוף השער הזה הוא מותר אינו בנסחת המחבר.
[2] It should be מזלות.
[3] An unnecessary dot after the word seems to have been effaced.
[4] Final ש in superscript.
[5] It should be 'בי, according to what Moses says in Chapters IX.2 ⟨1⟩ and ⟨7⟩, and IX.3 ⟨3⟩. The script of 'כ in 'מכ and 'בכ (as in many other words of the scribe’s script) is confusing and looks like 'ב, which would be a mistake.
[6] Between this word and the following, hand four has introduced two dots above and below the line, whose purpose is perhaps indicating that these are two separate words.

⟨II.4 The solstices and the equinoxes on the calendar scale⟩

⟨1⟩ Know that from the beginning of Aries the daytime increases until the sun is at the end of Gemini, when the daytime is the longest possible. ⟨2⟩ From the beginning of Cancer the daytime diminishes until the end of Virgo, when it [the daytime] and the nighttime have the same duration. ⟨3⟩ From the beginning of Libra the nighttime starts to increase until the end of Sagittarius, ⟨when⟩ the nighttime is the longest possible. ⟨4⟩ From the beginning of Capricorn the nighttime diminishes until the end of Pisces, when the nighttime and the daytime have the same duration.[1] ⟨5⟩ You know this from the months: when you place the alidade on one of these zodiac signs, it directly shows you the day and the month in which the daytime increases or diminishes. ⟨6⟩ You also know this by a different method, ⟨i.e., by⟩ knowing the degree of the sun; you shall understand the reason for this if you study well; this is enough.

⟨II.5 The diametrical opposite of the sun: Method one, by counting six zodiac signs⟩

⟨1⟩ The calculation of the diametrical opposite of the sun can be done [*lit.* explained] by several methods. ⟨2⟩ The first method consists of counting six zodiac signs from the ⟨next⟩ sign in which the sun is but looking at which degree of its sign the sun is placed. ⟨3⟩ One counts this number of degrees ⟨of the position of the sun⟩ in the zodiac sign that is the sixth ⟨in this counting⟩. ⟨4⟩ The last degree of it ⟨the counting of degrees in the sixth sign⟩ is the degree ⟨diametrically opposite⟩ to the sun.

⟨II.6 The diametrical opposite of the sun: Method two, by the meridian or the east-west line⟩

⟨1⟩ The second ⟨method⟩ consists of placing the degree of the sun ⟨on the rete⟩ on one extremity of the line of the meridian or of the east-west line. (47a) ⟨2⟩ The degree ⟨of the rete⟩ indicated by the other extremity of either of these two lines [the meridian or the east-west lines] is the diametrical opposite of the sun.[2]

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[1] Cf. Abraham Ibn Ezra's first version of his astrolabe text, where he explains the four quarters of the year according to the motion of the sun in the seasons, their months, and their corresponding zodiac signs (MS Paris BnF heb. 1053, ff. 7b–8a). The same as regards the second version, see MS Paris BnF heb. 1045, f. 189b. The third versions does not make any explicit reference to these astronomical phenomena.

[2] Methods one and two (in the same order) are referred to in Abraham Ibn Ezra's text on the astrolabe; see MS Paris BnF heb. 1053, f. 8a (first version). The second version only mentions it in the context of the calculation of the evening twilight without providing any definition; see MS Paris BnF heb. 1045, f. 193a. The same goes for the third version in which the expression (*nokaḥ ha-šemeš*) is referred to twice in the context of telling time by seasonal hours and a short definition is given according to Method one in Moses' text, and also in the context of the calculation of the end of the evening twilight; see MS Günzburg 937, ff. 7a and 8b, respectively. Moses' third method seems to be his contribution to the Hebrew literature on the subject.

<.4> <1> ודע שמראש טלה יגדל היום עד שילך השמש בסוף תאומים שבו יהיה היום היותר גדול שאפשר. <2> ומראש סרטן יקטן היום ועד סוף בתולה ישוה עם הלילה. <3> ומראש מאזנים יתחיל שיגדל הלילה ועד סוף קשת יהיה הגדול שאפשר. <4> ומראש גדי יקטן הלילה עד סוף דגים ישוה עם היום. <5> ותדע זה בחדשי<ם> כשתשי<ם> המעצר על מזל מאלו המזלות והוא יראך ביושרו באי זה יום וחדש יקטן או יגדל היום. <6> ודע זה עוד בדרך אחרת, ידיעת מעלת השמש אז יתבאר לך סבת זה אם תעיין היטב ודי זה.

<.5> <1> אמנם מציאות נכח השמש יתבאר בדרכים רבים. <2> הא' הוא שנמנה ששה מזלות מהמזל שמעלת השמש בו ונראה בכמה מעלות היה השמש ממזלו, <3> וכמו אותם המעלות נמנה מהמזל הששי, <4> והמעלה שאחריהם[1] היא מעלת <נכח> השמש.

<.6> <1> הב' הוא שנשים מעלת השמש בקצה הקו שהוא [חצי][2] השמים או בקצה הקו ההולך ממזרח למערב {~~חצי~~}[3] (47a) {~~היום~~}[4]. <2> והמעלה שיורה בה הקצה האחר [מ]אלו[5] הקוים הוא נכח השמש.

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[1] ם in superscript.
[2] Interlineal addition, hand two.
[3] Crossed out (rightly).
[4] Crossed out (rightly).
[5] Interlineal addition, hand two.

⟨II.7 The diametrical opposite of the sun: Method three, by great circles. Its demonstration⟩

⟨1⟩ The third method consists of placing the degree of the sun in the eastern horizon ⟨or the western horizon⟩. ⟨2⟩ The degree indicating the western horizon or vice versa is the diametrical opposite of the sun. ⟨3⟩ The reason for this is in Theodosius' book, who explains that any two great circles of the sphere intersect each other in the half.[1] ⟨4⟩ The circle of the zodiac is a great circle of the sphere as well as are the meridian, the right horizon, and the horizon, they are all great circles of the sphere. ⟨5⟩ We have represented each of these circles on the plane as if they were straight lines,[2] but they are great circles of the sphere and so they bisect the circle of the zodiac.

III CHAPTER: ON TAKING THE ALTITUDE OF THE SUN BY DAY AND OF THE STARS BY NIGHT

⟨III.1 The altitude of the sun by day⟩

⟨1⟩ The purpose is to know the value of the arc between the star and the horizon from the ⟨great⟩ circle of the zenith that extends from the zenith and crosses the star at that moment. ⟨2⟩ The procedure consists in taking the instrument by its ring with the right hand. ⟨3⟩ It should be perpendicular to the plane of the horizon and its front should face the object of observation. ⟨4⟩ If it is something emitting rays like the sun, move the alidade until the ray of the sun goes through the two sighting holes of the alidade, i.e., the ray enters the upper sighting hole and goes out from the lower one.

[1] This reference is to the *Sphaerica* written by Theodosius of Bithynia (circa 100 BCE), Book I, Proposition 12. For the Arabic and Latin medieval transmission of this work, see Lorch 1996; and Kunitzsch and Lorch 2010, 50–51 (I.12, Arabic and Latin versions of Proposition 12). For the Hebrew version, see also Lorch 2014, 255–258. For the Greek text, see Ver Eecke 1959; and Czinczenheim 2000. Kunitzsch and Lorch edited one (the anonymous) of the two Arabic translations (the other Arabic translation is by Qusṭā ibn Lūqā) and the shorter (Gerard of Cremona's version) of the two Latin versions that circulated from the 12th century (the longest is by Abraham bar Ḥiyya and Plato of Tivoli). For the Latin translation of Bar Hiyya and Plato of Tivoli, see Chabás 2011, 148–149; and Millás Vallicrosa 1949, 219–262. For the medieval Hebrew tradition of this text, specifically Moses ibn Tibbon's translation from Arabic into Hebrew, see, for instance, MS Madrid BNE 5474, ff. 191r–232v (בכדור).

[2] Except for the horizon line, which is the first almucantar or circle of altitude and is represented as a curve.

<.7> <1> השלישי שנשים מעלת השמש באופק המזרחי, <2> והמעלה שיורה בה האופק המערבי או בהפך הוא נכח השמש. <3> וסבת זה הוא מפני שנתבאר בספר תאודוסיוס שכל שתי עגולות שהם יותר גדולות שבכדור הן נחתכות[1] לחצאין. <4> וגלגל המזלות היא עגולה היותר גדולה שבכדור וכן גם כן קו אמצע השמים וקו אמצע מזרח ומערב ואופק מזרח ומערב הם עגולות היותר גדולות שבכדור, <5> אבל מפני ששמנו אותם[2] [בשטח נהיו][3] כל אחד מאלו העגולות ~~נהיו~~[4] כאלו הם קוים ישרים אבל הם [עגולות][5] היותר גדולות שבכרור, ולזה יחת{ו}כ[ו עם][6] עגולת המזלות לחצאין.

<III> שער[7] **בלקיחת** גובה השמש ביום והככבים בלילה.

<.1> <1> הכונה הנה בענין הוא השיעור שיש מהקשת שבין הככב והאופק מן העגולה היוצאת מנכח הראש ועוברת על הככב בעת ההיא. <2> והמעשה נקח הכלי בטבעתו ביד הימין <3> ויהיה נצב על שטח האופק ונחזור פנינו לצד הדבר המובט. <4> ואם הוא דבר שיש לו ניצוץ כגון השמש נניע הבריח עד שיקביל נצוץ השמש משתי נקבי המעצר רצו<ני> שיכנס הניצוץ {מהשמש}[8] מהנקב העליון ויעבור מהנקב התחתון.

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[1] Final ת in superscript.
[2] ם seems to be crossed out.
[3] Marginal addition, hand two.
[4] Crossed out (rightly if we incorporate in the text the marginal note).
[5] Interlineal addition, hand two.
[6] Interlineal addition, hand two. This hand also has marked as wrong the ו of the copyist and re-written the former ך as כ.
[7] Marginal note, hand one: ג'.
[8] Hand six indicated it as wrong (rightly).

⟨5⟩ On the altitude scale we count on which degree the end point of the alidade has fallen, i.e., the extremity that directly crosses through the hub of the instrument, which is its centre. ⟨6⟩ I mean how many degrees there are between the east[1] point and the degree on which the alidade has fallen. ⟨7⟩ The number of these degrees is the altitude of the sun for that location at that moment.[2]

⟨III.2 The altitude of any star or planet by night⟩

⟨1⟩ If you want to know the altitude of any of the fixed stars (47b) or planets, suspend the astrolabe from your right hand. ⟨2⟩ It should hang [*lit.* be supported] by itself perpendicularly to the plane of the horizon. ⟨3⟩ Close one of your eyes and raise and low the alidade until you completely cluster the light ⟨of the star or planet⟩ into the eye with which you are looking at the star ⟨or planet⟩, ⟨4⟩ so that the view goes from the first to the second sighting hole of the alidade. ⟨5⟩ Then count the degrees between the east point and the end point of the alidade,[3] as you did to take the altitude of the sun.

⟨III.3 What to do on a cloudy day⟩

⟨1⟩ You can also know the altitude of the sun when there are clouds hiding its ray. ⟨2⟩ In this case try [*lit.* consider] to observe the solar body ⟨rather than the solar ray⟩ through the sighting holes of the alidade, as you observe the stars.[4]

⟨III.4 Demonstration of these calculations⟩

⟨1⟩ The reason for what has been explained is that the arcs formed at equal angles between any ⟨number⟩ of circles with the same centre are similar to each other. ⟨2⟩ In other words, the ratio of the segment of the small arc ⟨of this angle⟩ to its circumference is as the ratio of the segment of the large arc of this angle to its circumference.

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[1] Marginal note: “That is, from the line of the instrument that corresponds (?) (*noḵeḥi*) to ⟨...⟩ the horizon.” There is text missing, for the manuscript was trimmed at some point. “The instrument” is written above the line.
[2] Marginal note: “If the sun is before, it is going ⟨up⟩ to the meridian line, which is mid⟨day⟩. But after the ⟨sun⟩ has crossed the meridian line, it is necessary to find the degrees between the line going down from the suspensory part of the astrolabe and the position of the ⟨west point of the horizon⟩ and add them to the 90 degrees of the ⟨corresponding⟩ quadrant that the sun have crossed ⟨...⟩. The result is the degrees ⟨of the altitude of the sun at that moment⟩.” There are several words missing or not legible because the manuscript was trimmed in the two borders. In the phrase “the degrees between the line,” “the degrees” is written above the line. This explanation does not make sense, perhaps because of the missing words.
[3] At this point it is clear that the author uses without distinction two words to refer to the alidade (מעצר and בריח).
[4] Abraham Ibn Ezra also refers this circumstance in two versions of his astrolabe text; see MSS Paris BnF heb. 1053, f. 7a (first version) and BnF heb. 1045, f. 189b (second version). There is nothing about this in the third version. Moses' wording of the whole calculation follows Ibn Ezra’s first version: “ואם רצית לדעת כמה גובה כוכב אחד מכוכבי גלגל המזלות או המשרתים תלה כלי הנחשת בימינך והסב פניך נגד הכוכב שתרצה לדעת מעלתו וסגור עינך אחת עד שתתקבץ כל האור אל העין השנית. והרם והשפל (7א) המעצר ותביט מהנקב הקטון אשר בלוח הרבוע האחד אשר בקצה המעצר הקרוב אליך עד שתראה הכוכב מן הנקב הקטון אשר בלוח הרבוע האחר אשר בקצה המעצר השנית. וכשעשית זה הבט ראש המעצר על כמה מעלות הוא עומד ותחל לספור מקצה מזרח וככה גובה הכוכב. גם ככה תוכל לדעת גובה השמש אם ידעת מקומה בגלגל ונסתרה ממראית העין ולא הייתה מאירה כמשפט בעבור שהסתירות עננים תשימנה כמו הכוכב ותדע גובה מעלתה.”

<5> ונמנה על כמה מעלות נפל קצה המעצר רצו<ני> הקצה העובר על יושרו מטבור הכלי שהוא מרכזו מעגולת הגובה, <6> רצו<ני> כמה מעלות מנקודת [המזרח][1] עד המעלה שנפל בה המעצר, <7> וכשיעור המעלות ההם הוא גובה השמש על הארץ [בעת ההיא][2].

<2.> <1> ואם רצית לדעת גובה ככב מהככבי<ם> (47b) הקיימים או מהמשרתים תלה הכלי בימינך. <2> ויהיה נסמך על עצמו נצב על שטח האופק. <3> וסגור עינך האחד והגבה והשפל המעצר עד שתקבץ כל האור אל העין אשר אתה רואה בה הככב, <4> {אחר כך תמנה המעלות מנקודת המזרח עד קצה}[3] עד שיעבור הראות מהנקב הא' עד הנקב הב' במעצר. <5> אחר כך תמנה המעלות מנקודת המזרח עד קצה הבריח כמו שעשית בגובה לקיחת השמש.

<3.> <1> גם ככה תוכל לדעת גובה השמש כאשר הסתירו נצוצו העננים. <2> והוא שתסכל לראות גוף השמש מתוך נקבי הבריח כאשר תביט הככבים.

<4.> <1> וסבת זה כי כבר התבאר שכל העגולות שמרכזם אחד הקשתות שיורכבו מהם על זויות שוות הם מתדמות. <2> ר<וצה> ל<ומר> שיחס חתיכת הקשת הקטנה אל עגולתה כיחס חתיכת הקשת מהגדולה הרוכבת על הזוית ההיא אל עגולתה.

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[1] Marginal note, hand two: ר"ל מן הקו [הכלי] שהוא נכחי ל[...] האופק. There is a word missing, for the manuscript was trimmed in the middle of the line. [הכלי] is written above the line with the same script as the marginal note.

[2] בעת ההיא is added at the end of the sentence by hand two. There is a marginal note, hand two: אם יהיה קודם בוא ה<שמש> בחצי השמים והוא חצי [...] אמנם אחרי עבור הש<מש> חצי השמים צריך למ[...] [ממעלות] מהקו היורד מתלית הכלי עד מקום המ[...] ולהוסיף עליהם צ' מעלות הרובע ש[...] עבר אותם השמש מהבוקר [עד חצי היום] והעולה [...] מעלות גובה השמש בעת ההיא ו the explanation continues but is not legible. There are several words missing, not legible, or hardly because the manuscript was trimmed in the two borders. [מעלות] is written above the line by a different hand from that of the marginal note and [עד חצי היום] is written above the line by the same hand of the marginal note.

[3] Rightly put between parentheses on the manuscript by an unidentified hand to indicate it as wrong. This sentence was copied by mistake, as its correct insertion two lines later on the MS shows (see III.2 ⟨5⟩).

⟨3⟩ It was already explained that the Earth does not have any noticeable size with respect to the sphere of the sun and much less with respect to anything placed above the sun.[1] ⟨4⟩ For this reason,[2] there is no difference between being in the ⟨very⟩ centre of the Earth or on its surface and, hereby, the centre of the instrument is like the centre of the Earth. ⟨5⟩ Consequently, the great circle⟨s⟩ of the sphere passing through the zenith of the head and ⟨the nadir⟩ of the feet [*lit.* foot] and the star, all have a single centre with the circle of the astrolabe.

⟨6⟩ A line extends between the centre of the instrument and the circle of the horizon and intersects the circle of its zenith at one point, ⟨7⟩ and thus one line radiates from the centre of the instrument up to the position of the sun or the star; ⟨8⟩ there is no difference whether this ray ⟨comes out⟩ from the observer or goes out from the thing observed.[3] ⟨9⟩ According to this, these circles become arcs through one centre and thus the arc between the east point (48a) and the position at which the end point of the alidade has fallen on the astrolabe[4] is similar to the arc of the circle of the sphere between the star and the horizon.

⟨10⟩ These circles are divided into equal degrees, i.e., each one is equally divided into 360 ⟨degrees⟩. ⟨11⟩ According to this, the degrees between the east point and the end point of the alidade are the degrees of the altitude of the sun or of any of the stars that we wanted. ⟨12⟩ Know that this is the very reason why there is no difference among the instruments, be they large or small. ⟨13⟩ Know that when you take the altitude of the sun when it [the sun] is among clouds its altitude is not true, for the science of optics has already explained that things observed when they are in the middle of a cloud are seen in positions that differ ⟨from their actual ones⟩.[5]

[1] See Ptolemy's *Almagest*, I, 6.

[2] The expression אם כן (*lit.* "if so," "that being the case") seems to be distinctive of Moses' style; see Chapters III.4 ⟨11⟩; IV.4a ⟨6⟩; IX.4 ⟨2⟩; XXII.2a ⟨7⟩; XXIII.6 ⟨7⟩; XXIII.7 ⟨9⟩; XXVIII.3 ⟨2⟩; XXVIII.6a ⟨4⟩; and XXVIII.6b ⟨17⟩.

[3] This is a brief reference to the two main theories of vision that circulated in the Middle Ages. The first combines the atomic theory of *simulacra* or *eidola* emanating from the visible object and penetrating the eye, or from the object to the eye, and the Aristotelian theory that understands the emanation from the eye as a form or quality. The second theory of vision was linked to Euclid and Ptolemy in the Middle Ages and claimed that the faculty of perception goes out from the observer to the visible object. There was a third theory, based on Galen and the Stoics, according to which vision takes place not because of a flow of material substance, either from the visible object to the eye or from the eye to the visible object, but because the transparent air that fills the space between the object and the observer mediates between both. For an overview of the complexities and nuances of these theories and their reception in the medieval period, see Lindberg 1976, 1–146. Moses, in his sentence in III.4, 8 is clearly eliding discussion about the nature of the vision as irrelevant for the practical problem he is dealing with, which is concerned not with the quality or the nature of the phenomenon but with the measurement of angles.

[4] So far, *aṣṭrolab*, *keli ha-neḥošet*, and *keli ha-habaṭah* have been used to refer to the astrolabe, which indicates the syncretism of sources for this text and points to the variety of authors and texts about astrolabes available in 16th-century Constantinople.

[5] Smith (transl.) 1996, 255–256 (V, 73). Ptolemy explains changes in the size of the image one perceives when the ray of light between the object and the eye passes through media of different densities.

<3> ולהיות שכבר התבאר שהארץ אין לה שיעור מורגש בערך אל גלגל השמש וכ<ל> ש<כן> אל מה שלמעלה ממנו. <4> הנה א<ם> כ<ן> אין הבדל בין היותינו במרכז הארץ או על שטחה ולזה יהיה מרכז הכלי בדמיון מרכז הארץ. <5> וא<ם> כ<ן> העגולה הגדולה שבכדור העוברת על נכח הראש והרגל והככב עם עגולת כלי הנחשת הם על מרכז אחד.

<6> ויצא קו ממרכז הכלי עד עגולת האופק בנקודת חתוכו עם עגולת נכח הראש הזאת, <7> וקו ניצוצי ממרכז הכלי אל מקום השמש או הככב. <8> ואין הבדל בין שיהיה זה הניצוץ מהמביט או יצא מהמובט. <9> הנה א<ם> כ<ן> אלו העגולות יהיו קשתות רוכבות על מרכז אחד ולזה יהיה הקשת שמנקודת (48a) המזרח עד מקום נפילת קצה המעצר בכלי ההבטה מתדמה לקשת מהעגולה שבכדור שבין הככב והאופק.

<10> ואלו העגולות יחלקו במעלות שוות רצו<ני> שכל אחת נחלקת על ש"ס בדמיון. <11> הנה אם כן[1] המעלות שמנקודת המזרח עד קצה המעצר הם מעלות גובה השמש או אחד מהככבים אשר רצינו מכלם. <12> ודע [שזאת][2] הסבה בעצמה היא הסבה כשאין הפרש בכלים בין שיהיה הכלי גדול או קטן. <13> ודע כי כשתקח גובה השמש כשהוא {בצ}[3] בתוך העבים אינו גבהו האמיתי שכבר התבאר בחכמת ההבטות שהדברים המובטים כשיובטו באמצעי עב יראו על זולת מקומם.

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[1] אם כן seems to be a distinctive expression in the language of the treatise and is repeated several times; see for example Chapters III.4 ⟨11⟩; IV.4a ⟨6⟩; IX.4 ⟨2⟩; XXII.2a ⟨7⟩; XXIII.6 ⟨7⟩; XXIII.7 ⟨9⟩; or XXVIII.3 ⟨2⟩.

[2] Interlineal correction, hand two. The original word is crossed out and is not legible.

[3] Hand six indicated these letters as mistake (rightly).

IV CHAPTER: TO KNOW THE HOURS OF THE DAY AND THE DIURNAL AND NOCTURNAL ARCS

⟨IV.1 Time can be measured either in equinoctial or in seasonal hours⟩

⟨1⟩ The hours of the day are of two classes: either equinoctial hours or seasonal hours. ⟨2⟩ Each equinoctial hour has 15 degrees, ⟨3⟩ but, for the seasonal ones, we take the complete diurnal arc, which is the separation between the upper part of the horizon and the parallel circle of the equator where the sun revolves during the corresponding daytime.[1]

⟨IV.2 Time in seasonal hours⟩

⟨1⟩ We divide it [the diurnal arc] always into 12 parts and find that the value of the arc of a ⟨diurnal⟩ seasonal hour, when the sun is among the northern zodiac signs, is more than 15 degrees. ⟨2⟩ However, when it [the sun] is among the southern zodiac signs, it [a diurnal seasonal hour] is always less than 15 degrees.[2] ⟨3⟩ To calculate with the astrolabe the hour of the day from the altitude of the sun, i.e., in seasonal hours, you need to know the position of the sun in the zodiac at that moment. ⟨4⟩ This is known through scales [*lit.* circles] engraved on the back of the instrument if you know the current day of the Christian month, as we have explained (48b) and as the sage Abraham Ibn Ezra explained it ⟨too⟩. ⟨5⟩ He also explained a second method, ⟨which⟩ we also intend to explain with God's assistance.[3]

⟨IV.3 Time in seasonal hours according to Abraham Ibn Ezra's method⟩

⟨1⟩ After knowing the position of the sun, place the rete over the ⟨latitude⟩ plate for your location and move the degree of the sun in the zodiac ⟨of the rete⟩ until it falls on the number of its altitude among the almucantars. ⟨2⟩ If it is before noon, place the degree of the sun among the eastern almucantars. ⟨3⟩ If it is after noon, place it among the western almucantars. ⟨4⟩ Look on the part ⟨of the latitude plate⟩ that is below the horizon, on which ⟨seasonal⟩ hour the diametrical opposite of the degree of the sun has fallen. ⟨5⟩ Count the hours between the line of the western horizon and the hour where the diametrical opposite of the sun has fallen. ⟨6⟩ These are the complete ⟨seasonal⟩ hours of the day that have elapsed. ⟨7⟩ The little that is taken of the next hour is the fraction of the current hour that has elapsed.[4]

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[1] The parallel circle of the equator is absent in each of Ibn Ezra's three treatises.
[2] The arc of the seasonal hour is exactly 15º at the equinoxes.
[3] Abraham Ibn Ezra's first method will be explained in the following section of the treatise (IV.3). The second method, which Moses ben Abraham relates to Abraham Ibn Ezra (but it is not according to the textual evidence), must be the one that Moses mentions as of "the proportions" (IV.4).
[4] These details suggest that Moses ben Abraham was well familiar with astrolabes and their uses. The method described so far is standard and not specific to Abraham Ibn Ezra. What is distinctive about Ibn Ezra is the set of steps given in the next section (IV.3, 8–14), especially the use of the first, intermediate and third marks and the first and second preservations. For more on the calculation of time in seasonal hours, using an astrolabe according to Abraham Ibn Ezra, see Appendix 1.

<IV> שער[1] לדעת[2] שעות היום וקשת היום והלילה.

<.1> <1> הנה שעות היום שני מינים, מהם שעות ישרות ומהם שעות מעוותות. <2> והישרות הם הנחשבות ט"ו מעלות בכל שעה, <3> ואמנם המעוותות הנה שנקח כל קשת היום והוא החלק שיבדילהו האופק למעלה מהעגולה הנכחית למשוה שעליה יסוב השמש ביום ההוא.

<.2> <1> ונחלקהו על י"ב חלקים תמיד עד שימצא שיעור קשת השעה המעוותות[3] בהיות השמש במזלות הצפוניות יותר מט"ו מעלות, <2> ובהיותו במזלות הדרומיות יהיה פחות מט"ו מעלות תמיד. <3> והנה לדעת השעה מהיום בכלי מצד ידיעת גובה השמש רצו<ני> בשעות המעוותות צריך שתדע מקום השמש מהמזלות בעת ההיא. <4> והוא יודע עם העגולות המצויירות בגב הכלי בידיעתך יום החדש הנוצרי שאתה בו כמו שבארנו אנחנו (48b) וכמו שביאר זה החכם ר<בי> א<ברהם> ב<ן> ע<זרא>, <5> וביאר עוד דרך שנית וגם אנחנו עתידים לבארה בע<זרת> ה<שם>.

<.3> <1> ואחר שידעת מקום השמש שים הרשת על לוח ארצך והניע מעלת השמש מאזור המזלות עד שתפול בגשרים על מספר גבהו. <2> ואם היה קודם חצי היום שים מעלת השמש בצד הגשרים המזרחיים. <3> ואם הוא אחר חצי היום שים אותו בצד הגשרים המערביים. <4> וראה המעלה הנכחית למעלת השמש בשטח שתחת האופק על אי זו מהשעות נפלה. <5> ומנה השעות שמקו האופק המערבי עד [ש]המעלה[4] השעה הנכחית למעלת השמש נפלה עליה. <6> והם השעות השלמות שעברו מהיום, <7> וקצת מה שחתך מהשעה הנמשכת להן הוא החלק שעבר מהשעה שאתה עומד בה.

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[1] Marginal note, hand one: 'ד.
[2] The first words of the title of this chapter are not in bold script.
[3] It should be המעוותת.
[4] Interlineal addition (ש), hand two. Hand seven mark this word with two dots and the following with one to indicate (rightly) an exchange in their order, so that one reads השעה שהמעלה rather than שהמעלה השעה.

⟨8⟩ You know this as follows: mark ⟨the position of the degree⟩ with the beginning of Capricorn, which is the tool that serves to indicate on the limb; this mark is called the [intermediate][1] mark [*M1*]. ⟨9⟩ Turn the rete until ⟨this⟩ degree falls on the beginning of the hour and mark on the limb ⟨the position of the degree⟩ with the beginning of Capricorn;[2] this is called the first mark [*M3*]. ⟨10⟩ Turn the rete again until the degree of the sun falls on the end of this hour and make the second mark [*M2*]. ⟨11⟩ Count the number of the degrees between the two marks [the first and the second, *M2*-*M3*] and keep it, this is called the first preservation.[3] ⟨12⟩ Find again the degrees between the first and the intermediate mark⟨s⟩ [*M3*-*M1*] and call it the second preservation. ⟨13⟩ Divide the value of the hour, which is 60 minutes, by the first preservation [the degrees of the seasonal hour]. ⟨14⟩ Multiply the result of the division by the second preservation [the interval of time elapsed]; the result is the minutes of the current hour that have elapsed.

⟨IV.4 Time in seasonal hours according to the method of the proportions⟩[4]

⟨1⟩ You can also find it [the time in seasonal hours] by the method of the proportions: multiply the second preservation by 60 and divide the result by the first preservation. ⟨2⟩ The quotient is the minutes of the current hour that have elapsed.[5] (49a) ⟨3⟩ Know that if you place the degree of the sun among the almucantars, according to its altitude, and localize on the instrument the almucantar on which the sun is placed, considering if the instrument is medial, tertial, and so on, you do as I am going to explain in the following chapter, with God's help.[6]

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[1] "Intermediate" is my correction of "first," written in the manuscript.

[2] "Mark on the limb with the beginning of Capricorn" is Moses ben Abraham's literal expression, which is exactly the same as that which Ibn Ezra uses. Cf. Moses ben Abraham's expression סמן עם ראש גדי (for example Chapter IV.3 ⟨8⟩–⟨9⟩) and Ibn Ezra's סמן עם ראש גדי (first version, MS Paris BnF heb. 1053, f. 8b), שים סימן עם ראש גדי (second version, MS Paris BnF heb. 1045, f. 191a), and עשה סימן בחיק עם ראש גדי (third version, MS Gunzburg 937, f. 5b).

[3] For a similar explanation in Ibn al-Samḥ's text (979–1035), see Viladrich i Grau 1986, 110 (Ch. VI): "És posible que l'oposat del grau del sol no caigui sobre una de les línies de les hores an ses trobi entre dues d'elles. Resultarà així que aquella hora no haurà acabat encara i hauràs de determinar el temps que ha passat segons això que descriure tot seguit. Col·loca el grau del sol sobre la posició que calgui als almucantarats en funció del que hagis determinat amb anterioritat. Fes un senyal sobre la corona amb l'índex dels graus, que serà el primer senyal. Tot seguit, situa l'oposat del grau del sol sobre la línia de l'hora que és en aquell moment, i fes un altre senyal amb l'índex, que serà el segon. Desplaça l'oposat del grau del sol sobre la línia de la fi de l'hora i fes sobre la corona el tercer senyal. A continuació coneixeràs quant hi ha entre els senyals segon i tercer, que serà el temps d'una hora d'aquell dia. Guarda-ho. Després comptarás el que hi ha entre el primer i el segon senyal que serà la fracció de l'hora. Desbrinaràs el seu valor en temps de les hores d'aquell dia que has guardat i el resultat serà el que ha passat d'aquella hora, si Déu vol." Notice that Ibn Ezra's distinctive terminology (the term "preservation") is not found in Ibn al-Samḥ's treatise.

[4] Ibn Ezra is clearly the source of what Moses refers to as the "the method of the proportions" to calculate time in seasonal hours with an astrolabe, although Moses omits any mention of Ibn Ezra as regards this specific method. For this method in Ibn Ezra (who does not name it in any specific way), see Appendix 1.

[5] IV.4 ⟨1⟩–⟨2⟩ is attested only in the second version of Ibn Ezra's astrolabe text. A comparison of Ibn Ezra's three versions of this calculation shows that Moses ben Abraham followed the second version of Ibn Ezra's astrolabe text (composed in Verona in 1146 and available, it seems, in Constantinople at the beginning of the 16th century).

[6] Chapter XXV (see below) explains how to know the time if there is no latitude plate for one's latitude among the plates of the astrolabe. The procedure suggests that one calculates the time with two plates, one for a latitude larger, the other for a latitude smaller than one's location, and then interpolates between the corresponding values to get the time in one's latitude. It should be noted that in Ottoman times the practice was to tell time in equinoctial hours, but starting the day at sunset. See King 2004, 1:207–208; and Wishnitzer 2015, 30–44, 62, and 204 n. 57. Jews living in Ottoman lands would count hours according to the local customs.

<8> וזה תדענו[1] כן. סמן עם ראש גדי ששם המורה בתא[2] ויקרא זה סימן ראשון[3]. <9> עוד סבב הרשת עד שתפול המעלה על תחלת השעה וסמן עם ראש גדי בתא, ויקרא זה סימן ראשון. <10> עוד סבב הרשת עד שתפול מעלת השמש בקצה השעה ההיא וסמן סימן שני. <11> ודע מספר המעלות שבין שני הסימנים ושמרם, ויקראו שמור ראשון. <12> עוד דע המעלות שבין הסימן הראשון והאמצעי וקראם שמור שני. <13> וחלק שיעור השעה שהוא ס' דקים על השמור הראשון, <14> והיוצא מהחלוק ערוך על השמור השני והעולה הם דקים שעברו מן השעה שאתה עומד בה.

<4.> <1> או תוציאהו בדרך הערכין וזה שתכה השמור השני בס' והעולה תחלק על השמור הראשון, <2> והיוצא יהיו הדקים שעברו מהשעה (49a) שאתה בה. <3> ודע כי כאשר שמת מעלת השמש בדמיון גובהו בגשרים ולאלו מצאת הגשר שהשמש בו בכלי כגון שהיה הכלי חצי או שליש או זולתו, תעשה כדרך שאפרש בשער הבא ב<עזרת> ה<שם>.

[1] Interlineal mark (two dots), hand seven; it is clearly not an indication of mistake.
[2] Interlineal mark (two dots), hand seven; it is clearly not an indication of mistake.
[3] It should be סימן אמצעי.

⟨IV.4a Demonstration of the method of the proportions⟩

⟨1⟩ You already knew the reason for this, which is that the sun turns every day on circles parallel to the equator.[1] ⟨2⟩ It is already explained—to whomever understands the proposition in ⟨Chapter⟩ 3 of our previous sections [chapters]—that the circle of the horizon divides the circles parallel to the equator, either northern or southern, according to the ratio of their division in the sphere.[2] ⟨3⟩ You already knew that the part of the circle parallel to the equator that is above the horizon, which embraces the diurnal arc, is always divided into 12 equal parts. ⟨4⟩ Each of these parts is the arc of a seasonal hour of the corresponding day.

⟨5⟩ It is also apparent that the altitude of the sun above the horizon results from its progressive rising from circle to circle among the circles parallel to the horizon. ⟨6⟩ According to this (אם כן), when the altitude of the sun is, for example, 20 degrees, it is in the circle parallel to the horizon whose altitude with respect to the horizon is 20 degrees. ⟨7⟩ Being this so, the almucantars, which are the circles parallel to the horizon, intersect these circles parallel to the equator. ⟨8⟩ These circles ⟨parallel to the equator⟩ pass through the points of the intersections that determine the arcs of ⟨each⟩ hour. ⟨9⟩ The same holds for the points of the intersections of every circle parallel to the equator.

⟨10⟩ When you make the rete turn around the pole [i.e., the centre of the astrolabe and of the rete] with the daily movement [i.e., rightwards or westwards], the ⟨position of the⟩ degree of the sun changes on the surface ⟨of the astrolabe⟩ according to this circular motion, as does the ⟨corresponding⟩ circle parallel ⟨to the equator⟩ on which this zodiac degree circumvolves the sphere. ⟨11⟩ This is apparent to whomever understands the foundation of this craft. ⟨12⟩ When the circles parallel (49b) to the horizon intersect one of the circles [of the sun], they also intersect it in the sphere accordingly, for it has become clear that the division [*lit.* root] engraved on the surface [of the astrolabe] agrees with the corresponding division of them [the circles] in the sphere. ⟨13⟩ For this reason, the place of the intersection of the circle parallel to the horizon, whose altitude with respect to the horizon is—let's say—20 degrees is the place of the intersection of the almucantar that is 20 degrees away from the horizon.

⟨14⟩ Consequently, when we place the degree of the sun, according to its altitude, among the almucantars, we place it in the circle parallel to the equator in which the sun turns ⟨in the arc⟩ between the point of the intersection with the horizon and the point intersecting the almucantar. ⟨15⟩ ⟨This arc⟩ is similar to the arc of this circle of the sphere that is delimited between the horizon and the circle parallel to the horizon, whose distance from the horizon is the altitude.[3] ⟨16⟩ This arc of this circle indicates the part of the day that has elapsed.

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[1] The two small circles, parallel to the equator that the sun describes on the longest and the shortest days, are the Tropics of Cancer and Capricorn. The sun travels on daily parallels between the Tropics, which are circles of equal declination. The always visible circle of declination can be used as a measure of terrestrial latitude, which is more frequently found by the height of the pole on the meridian.

[2] This is the first of five specific self-references by Moses ben Abraham to "books," which must be understood as chapters, of his treatise on the astrolabe (IV.4a ⟨2⟩ and ⟨19⟩; X.3; XII.2 ⟨5⟩; and XV.2a ⟨2⟩). Here the reference is to Chapter III.4.

[3] The Hebrew passage is confusing, but the meaning is that this arc is the part of the diurnal circle the sun has passed.

<4א.> <1> וסבת זה כי כ[ב]ר[1] ידעת שהשמש יסוב בכל יום על עגולות נכחיות למשוה. <2> וכבר יתבאר למבין תמונת בג' מספרינו הקודם לזה שעגול האופק יחלק העגולות הנכוחיות למשוה בין הצפוניות בין הדרומיות על יחס חלוקו אותם בכדור. <3> וידעת שהחלק שממעל לאופק מהעגולה הנכחית למשוה שהיא בכללה קשת היום תחלק תמיד על י"ב חלקים שוים, <4> שכל חלק מהם הוא קשת השעה המעוותת ליום ההוא.

<5> וגם מבואר שגובה השמש על האופק יהיה בעלותו בהדרגה מעגולה לעגולה מהעגולות הנכוחיות לאופק. <6> ואם כן כאשר יהיה גובה השמש כ' מעלות ד<רך> מ<של> הוא בעגולה הנכחית לאופק שגובהה על האופק כ' מעלות. <7> וכאשר היה זה כן והיו הגשרים שהם העגולות הנכוחיות לאופק ויחתכו אלו העגולות הנכוחיות למשוה. <8> הנה אלו העגולות יעברו על מקומות חתוכי קשתות השעה. <9> וכן על מקומות חתוכי כל עגולה מהנכחית למשוה.

<10> וכאשר תסובב הרשת על קוטב בתנועה הכללית הנה מעלת השמש תחדש בשטח בסבובה עגולה היא בדמיון העגולה מן העגולות הנכוחיות שתסוב עליה המעלה ההיא מן המזלות בכדור, <11> כאשר מבואר למבין שרש המלאכה. <12> ואחר שאחת העגולות יחתכוה העגולות הנכוחיות (49b) לאופק בדמיון הוא שיחלקוה בכדור אחר שהתבאר ששורש הנחתם בשטח מסכים עם אשר יהיה מהם בכדור. <13> ולכן במקום שתחתוך העגולה הנכחית לאופק שגובהה על האופק ד<רך> מ<של> כ' מעלות שם יחתכנה הגשר שהוחק בשטח רחוק מהאופק כ' מעלות.

<14> הנה [א<ם> כ<ן>][2] כאשר שמנו מעלת השמש על דמיון גובהו בגשרים, הנה שמנו אותו בעגולתו הנכחית למשוה שיסוב בה השמש אשר מנקודת חתוכה עם האופק עד הנקודה שנחתכה עם הגשר <15> מתדמה לקשת שנחתכה מהעגולה ההיא בכדור שבין האופק ובין העגולה הנכחית לאופק שמרחקה מהאופק בדמיון הגובה. <16> וכאשר היתה זאת הקשת מזאת העגולה היא מורה על החלק שעבר[3] מן היום.

[1] Interlineal addition, hand two (the original letter is illegible by a blot of ink).
[2] Interlineal addition, hand two.
[3] ר written in superscript.

⟨17⟩ The division of the arc similar to it was already divided [i.e., the diurnal arc]. ⟨18⟩ This arc is ⟨the section⟩ below the horizon where the degree diametrically opposite to the degree of the sun revolves the 12 equal divisions of the ⟨diurnal⟩ horary arcs according to the resulting arc of the hour. ⟨19⟩ We have explained these horary arcs in ⟨one of⟩ our previous sections [chapters].[1] ⟨20⟩ If the degree falls on the first horary arc, therefore (אם כן) it falls on one of the 12 equal divisions into which the ⟨diurnal⟩ arc has been divided. ⟨21⟩ (אם כן) This is the first hour of the daytime, and so on for the remaining hours.

⟨22⟩ As this circle parallel to the equator shares the same centre with the circumference of the surrounding ⟨circle⟩ [i.e., the limb on the astrolabe], the arc between the two marks [the first and the second] is similar to one of the 12 arcs that divide this parallel circle below the horizon. ⟨23⟩ For this reason, the number of the degrees between the two marks is the value of the arc of the seasonal hour.

⟨24⟩ We have been (50a) long with this because we heard from one of the experts in the craft that the understanding of this question [i.e., the division of the seasonal hours and how they work on the astrolabe] is one of the most difficult parts in this science,[2] ⟨25⟩ that not even one among one thousand ⟨could⟩ deal with it. ⟨26⟩ Indeed we did not deal with it except for the time it took us to write it; it is not a difficult question, as has been thought.[3]

⟨IV.5 The equinoctial hours from the seasonal ones⟩

⟨1⟩ From what we have said, it is clear how to calculate the value of the equinoctial hours of the day that have elapsed. ⟨2⟩ This is indicated by the beginning of Capricorn [i.e., the *almuri* or indicator] on the limb when we place the degree of the sun according to its altitude among the eastern almucantars before noon and among the western ones after noon. ⟨3⟩ Then we mark with the beginning ⟨of Capricorn⟩ the place of the limb at which the [solar degree][4] has fallen. ⟨4⟩ We turn the rete in the opposite direction, i.e., from west to east, until the degree of the sun falls on the east line ⟨of the horizon⟩. ⟨5⟩ We mark on the limb where the beginning of Capricorn has fallen and observe the degrees between the two marks. ⟨6⟩ We divide them [these degrees] by 15, which is the number ⟨of the degrees⟩ of one equinoctial hour. ⟨7⟩ The result is the value of the equinoctial hours of the day that have elapsed. ⟨8⟩ If degrees are left which do not complete ⟨one hour, which is⟩ 15 degrees, we multiply them [the degrees that are left] by 4, which is the number of the minutes in one [degree][5]. ⟨9⟩ It is apparent that the arc of the circle parallel to it [the equator] on which the sun circumvolves and the circle of the limb are similar, and this is enough.

[1] Reference to the previous section IV.2–4 of this Chapter.

[2] The Hebrew word for “craft” (*melaḵah*) and the Hebrew word for “science” (*ḥoḵmah*) are both being used in this paragraph to refer to the art or technique of using and understanding astrolabes.

[3] This indicates how well Moses ben Abraham thought he mastered his field.

[4] “Solar degree” is my correction of “beginning of Capricorn,” written in the manuscript.

[5] “Degree” is my correction of “hour,” written in the manuscript. If the sun moves 15 degrees every equinoctial hour, then 60 / 15 = 4 minutes (of time) per degree of arc.

<17> וכבר נחלקה החתיכה מהקשת המתדמה לה, <18> שתחת האופק שעליה תסוב המעלה הנכחית למעלה[1] השמש על י"ב חלקים שוים עם הקשתות המוצאות לקשת השעה, <19> כמו שביארנו בספרינו הקודם לזה. <20> הנה אם נפלה המעלה על קשת השעה הראשונה נפלה א<ם> כ<ן> על חלק אחד מהי"ב חלקים שוים שנחלק הקשת. <21> והנה א<ם> כ<ן> אז הוא שעה אחת מהיום, וכן בזולתה מהשעות.
<22> ומפני שזאת העגולה הנכחית למשוה היא על מרכז אחד עם העגולה אשר בקו הסובב הנה הקשת שבין שני הסימנין מתדמה לחלק הקשת מהי"ב שנחלקה בהם העגולה ההיא הנכחית שמתחת לאופק. <23> ולכן יהיו שיעור המעלות ההן שבין שני הסימנין הם שעור קשת השעה המעוותת.
<24> ודי בזה עם (50a) שהארכנו בו למה ששמענו מאחד המבינים במלאכה שהידיעה בסבת זה היא מהידיעות הקשות שבזו החכמה, <25> לא יעמדו עליה אחד מני אלף. <26> אך אנחנו לא עמדנו עליו זולת הזמן שנתאחרנו בכתיבתו ואינו דבר קשה כלל כפי מה שחשב.

<.5> <1> **ויתבאר** ממה שאמרנו איך נדע שעור השעות השוות שעברו מן היום {~~עד~~}[2]. <2> וזה שנרשום עם ראש גדי בתא בשומנו מעלת השמש על דמיון גובהו בגשרים במזרחיים עד חצי היום ובמערביים אחר חצי היום, <3> ונסמן עם ראש נפילת ראש גדי[3] בתא. <4> ונסבב הרשת הפך תנועתה רצו<ני> ממערב למזרח עד שתבוא מעלת השמש על קו המזרחי. <5> ונסמן עם נפילת ראש גדי בתא ונראה המעלות שבין שני הסימנין. <6> ונחלקם על ט"ו שהם שיעור השעה השוה, <7> והיוצא הם שעור השעות השוות שעברו מן היום. <8> ואם נשארו מעלות שלא השלימו לט"ו תערכם[4] על ד' והעולה הוא דקי השעה[5]. <9> וזה מבואר כי קשת העגולה הנכחיים שעליה יסוב השמש עם עגולת התא הם מתדמות ודי בזה.

[1] It should be למעלת.
[2] Crossed out (rightly).
[3] It should be מעלת השמש rather than ראש גדי.
[4] Written תערבם.
[5] It should be מעלה.

⟨IV.6 The diurnal and the nocturnal arcs⟩

⟨1⟩ If you want to know the degrees of the diurnal arc, place the degree of the sun on the line of the eastern horizon. ⟨2⟩ Mark on the limb ⟨the position⟩ of the beginning of Capricorn and move the rete in the direction of the daily motion [rightwards] until the degree of the sun falls on the western horizon. ⟨3⟩ Mark on the limb ⟨the position⟩ of the beginning of Capricorn; the degrees between the two marks are the diurnal arc that you are seeking. ⟨4⟩ Subtract them from 360 and the remainder you obtain is the nocturnal arc. ⟨5⟩ If you divide the diurnal arc by 15, the result you get is ⟨the number of equinoctial⟩ hours of that day and the same (50b) for the nocturnal arc. ⟨6⟩ If you know the arc of the seasonal hour of the day, subtract it from 30,[1] and you get the ⟨corresponding⟩ seasonal hour of the night.

⟨IV.7 What to do if the astrolabe does not have seasonal hour divisions⟩

⟨1⟩ Know that if your astrolabe does not have seasonal hour divisions but you want to know the seasonal hours of the daytime that have elapsed, find the diurnal arc and keep it. ⟨2⟩ This is called the first preservation. ⟨3⟩ Then find the ⟨part of the⟩ diurnal arc that has elapsed in the following way. ⟨4⟩ When you place the degree of the sun among the almucantars according to its altitude, mark on the limb ⟨the position⟩ of the beginning of Capricorn. ⟨5⟩ Move the rete in the direction opposite to the daily motion [leftwards or eastwards] until the degree of the sun is on the eastern horizon. ⟨6⟩ Mark on the limb ⟨the position⟩ of the beginning of Capricorn and count the degrees between the two marks; this is the value of the diurnal arc that has elapsed. ⟨7⟩ Call it the second preservation. ⟨8⟩ The ratio of the hours that have elapsed to 12 is the ratio of the second preservation to the first.

⟨9⟩ You proceed according to the method of the proportions: ⟨10⟩ Multiply the second preservation by 12 and divide the result by the first preservation;[2] ⟨11⟩ the quotient is the hours of the day that have elapsed until that moment. ⟨12⟩ You can also divide the first preservation by 12 and the result is the arc of the ⟨seasonal⟩ hour. ⟨13⟩ Divide the second preservation by this arc of the hour ⟨you got in the previous division⟩, and you shall obtain the seasonal hours of the day that have elapsed. ⟨14⟩ If there is a remainder of the degrees in the division, multiply the remainder by 60 ⟨minutes of arc⟩. ⟨15⟩ Divide the result by the arc of the hour and the quotient is ⟨the number of⟩ the minutes of the current hour, and this is enough.[3]

[1] Since the twelve seasonal diurnal hours are equal to each other, and the twelve seasonal nocturnal hours are equal to each other, a diurnal hour and a nocturnal hour together will be 1/12 of 360º, that is, will be 30º. Therefore subtracting one of these hours (diurnal or nocturnal) from 30º will give the length of the other one (nocturnal or diurnal).

[2] Despite the fact that the technique has precedents in Arabic sources (the already mentioned Ibn al-Samḥ's treatise), the specific reference to the first and the second "preservations" is unique in astrolabe texts and clearly indicates that Abraham Ibn Ezra is the source (although Ibn Ezra uses the term "preservation" in his descriptions of uses other than the one described here).

[3] Unusual in astrolabe treatises, but distinctive in Moses ben Abraham's text, is his concern with the astrolabe as an instrument to tell time, which is a use often underrated in other astrolabe texts that are more concerned with astronomical/astrological uses.

<6.> <1> **ואם** רצית לדעת מעלות קשת היום תשים מעלת השמש על קו האופק המזרחי, <2> וסמן עם ראש גדי בתא והניע הרשת בסדר התנועה הכללית עד שתחנה מעלת השמש באופק המערבי. <3> וסמן עם ראש גדי בתא והמעלות שבין שני הסימנין הם קשת היום הדרושה. <4> גרעם מש"ס ותשאר בידך קשת הלילה. <5> ואם תחלק קשת היום על ט"ו יצאו לך שעות היום ההוא וכזה (50b) בקשת הלילה. <6> ואם ידעת קשת השעה המעוותת ביום תגרעם מל' ותצא השעה המעוותת מן הלילה.

<7.> <1> **ודע** שאם לא יש[1] בכלי שלך קשת השעות המעוותות ותרצה לדעת השעות המעוותות שעברו מהיום דע קשת היום ושמרהו, <2> ויקרא השמור הראשון. <3> עוד דע הקשת שעברו מהיום בזה האופן, <4> והוא שכאשר שמת מעלת השמש על דמיון גובהו בגשרים סמן עם ראש גדי בתא. <5> עוד הניע הרשת הפך תנועתה הכללית עד הנחת מעלת השמש על האופק המזרחי. <6> וסמן עם ראש גדי בתא ומנה עם[2] שבין שני הסימנין מן המעלות ותהיה שעור הקשת שעברה מהיום, <7> ותקרא השמור השני. <8> וכערך השמור השני מן הראשון כך ערך השעות שעברו מהיום על[3] י"ב.

<9> ותעשה בדרך הערכין כן: <10> הכה השמור השני בי"ב וחלק העולה על השמור הראשון, <11> ויצאו שעות שעברו מן היום עד העת ההיא; <12> או חלק השמור הראשון על י"ב ויצא קשת השעה. <13> חלק השמור השני על קשת השעה ויצאו לך שעות מעוותות שעברו מהיום. <14> ואם נשארו מעלות בחלוק הכה הנשאר ההוא בס'. <15> וחלק העולה על קשת השעה והיוצא הנה הם דקי השעה שאתה עומד בה ודי בזה.

[1] The standard form should be שאם אין בכלי rather than שאם לא יש בכלי. Might this be an indication of a possible influence of Moses ben Abraham's native language (Castilian)? Or the scribe's?

[2] It should be מה.

[3] It should be אל.

V CHAPTER: TO KNOW THE RISING DEGREE IN THE EAST AND THE THREE REMAINING ANGLES

⟨V.1 The ascendant with a complete instrument and with one not complete⟩[1]

⟨1⟩ Place the degree of the sun among the almucantars according to its altitude and observe the degree of the zodiac that is at the east extremity [i.e., the east point of the horizon]; ⟨2⟩ it is the rising degree for that moment. (51a) ⟨3⟩ If the instrument is complete, you have on it all the almucantars ⟨for every degree of altitude, i.e., 90 almucantar circles⟩.[2]

⟨4⟩ If the instrument is medial, tertial, etc., and the almucantar for the altitude of the sun is not there, place the degree of the sun on the previous almucantar and mark [*M1*] on the limb ⟨the position⟩ of the beginning of Capricorn. ⟨5⟩ Place now the degree of the sun on the following almucantar and mark [*M2*] on the limb ⟨the position⟩ of the beginning of Capricorn. ⟨6⟩ Count how many degrees there are between the two marks [*M2*-*M1*]; there are, for example, 12 degrees. ⟨7⟩ Observe the distance between the altitude of the sun and the preceding [almucantar][3] [*M1*], I mean, if there is one degree, two, ⟨et cetera between them⟩; let us say that the distance ⟨between the solar altitude and the preceding almucantar⟩ is 5 degrees. ⟨8⟩ Also count how many degrees there are between ⟨every two⟩ almucantars, ⟨for example,⟩ 6 [*A*] or similar [i.e., nine or ten].[4] ⟨9⟩ You take from 12 degrees [*M2*-*M1*], according to the value that corresponds ⟨in the proportion⟩, for instance, if there are 12 ⟨degrees of difference between the marks on the limb⟩ corresponding to ⟨6⟩ degrees between the two almucantars, then to 5 ⟨degrees between the position of the sun and the preceding almucantar⟩ corresponds 10 degrees ⟨on the limb⟩. ⟨10⟩ Count 10 degrees from the first mark [*M1*] to the side of the motion of the rete [rightwards]. ⟨11⟩ At the place where the counting ends make the intermediate mark [*M3*]. ⟨12⟩ Move the rete in the direction of the daily motion [rightwards], until the beginning of Capricorn falls on the intermediate mark [*M3*]. ⟨13⟩ The place between the two almucantars at which the degree of the sun falls represents the degree of the altitude of the sun that you were looking for.[5] ⟨14⟩ You do this when there is no almucantar for the specific ⟨solar⟩ altitude on your instrument, and when you have done it, observe the degree ⟨of the rete falling⟩ on the east line ⟨of the horizon⟩; it is the rising degree.

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[1] Another remark on the necessity of knowing the caliber of the astrolabe, not only to perform calculations, but also to understand the accuracy of the instrument.

[2] To this point, the procedure is standard in astrolabe texts; what Moses adds is how to deal with the calculation when one does not have a plate with single-degree divisions for the ninety almucantars. Very few extant early astrolabe plates depict ninety almucantars.

[3] "Almucantar" is my correction of "mark," written in the manuscript.

[4] I.e., the almucantar division in this case cannot be lower than 6 degrees.

[5] $M1 + A \times \{(M3 - M1) / (M2 - M1)\}$, where A is the distance between two almucantars on the instrument (the caliber of the instrument). The result is where to place the indicator/almuri to get the actual position of the altitude of the sun when this falls between two almucantars.

<V> שער[1] לדעת המעלה[2] הצומחת בקצה המזרח ושאר השלשה יתדות.

<.1> <1> שים מעלת השמש בדמיון גובהו בגשרים וראה מעלת המזלו<ת> שעם קצה המזרחי, <2> והיא המעלה הצומחת לעת ההיא. <3> וזה (51a) אם הכלי שלם ויש לך כל הגשרים בו.

<4> אך אם הכלי חצי או שליש וזולתו ולא יהיה שם הגשר שגובה השמש הוא בו, שים מעלת השמש על הגשר הקודם וסמן עם ראש גדי בתא. <5> עוד שים מעלת השמש על הגשר הבא וסמן עם ראש גדי בתא. <6> ודע כמה מעלות בין שני הסימנין והיו[3] ד<רך> מ<של> י"ב מעלות. <7> וראה מרחק גבהות השמש מהסימן[4] הקודם רצו<ני> אם מעלה אחת או שתי<י>ם, ויהיו ד<רך> מ<של> המרחק ה' מעלות. <8> גם דע כמה בין גשר לגשר ו' מעלות ודומה לו. <9> ותקח מהי"ב מעלות כפי הערך שתאחר, ד<רך> מ<של> אם י"ב ממעלות[5] בין גשר לגשר כמה ראוי לה' מעלות והנה ראוי י' מעלות. <10> ומנה מהסימן הראשון לצד תנועת הרשת י' מעלות, <11> ובמקום שיכלה סמן סימן אמצעי. <12> והניע הרשת דרך התנועה הכללית עד שיפול ראש גדי בסימן האמצעי. <13> ובמקום שתפול מעלת השמש בין גשר לגשר היא מעלת דמיון גובה השמש שרצית. <14> וכן תעשה כשלא יהיה הגשר שבדמיון הגובה נמצא בכלי וכאשר עשית זה תראה המעלה שהיא עם קו המזרח והיא המעלה הצומחת.

[1] Marginal note, hand one: 'ה.
[2] The title of this chapter is not in bold script.
[3] The initial ו of the word looks like marked as a number, but it is just ו.
[4] It should be מהגשר.
[5] Hand six crossed out one letter (not legible because of the ink) that is placed after the first מ; I have not transcribed it.

⟨V.2 The remaining three angles⟩

⟨1⟩ ⟨The degree⟩ that is diametrically opposite to it [the rising degree] at the western extremity of the horizon is the descending degree. ⟨2⟩ The degree on the upper meridian is the cusp of the tenth house, which is the midheaven. ⟨3⟩ The degree on the lower meridian is the cusp of the fourth house, which is called the angle of the earth, and this is enough.[1]

VI CHAPTER: TO KNOW THE HOURS OF THE NIGHTTIME

⟨VI.1 Time in seasonal hours using the altitude of any fixed star⟩

⟨1⟩ When you take the altitude of any of the ⟨fixed⟩ stars that you know are engraved on the astrolabe, place the pointer of the star among the almucantars according to its altitude. ⟨2⟩ If it [the star] is in the east, (51b) place it [the star pointer] among the eastern almucantars, but if it is in the west, place it among the western almucantars. ⟨3⟩ If it [the star] is on the meridian, leave it and take another star placed in the east or in the west.[2] ⟨4⟩ Look on which horary arc [hour line] the degree of the sun has fallen and count their number ⟨of degrees⟩ from the western line of the horizon [which is the first hour]. ⟨5⟩ They are the seasonal hours of the nighttime that have elapsed. ⟨6⟩ The degree of the zodiac at the eastern extremity of the horizon is the ascendant. ⟨7⟩ The remaining angles are placed as we have previously said.[3]

⟨VI.2 Time in equinoctial hours using the altitude of any fixed star⟩

⟨1⟩ The reason of this is clear in itself, for we determine the situation of the sphere according to what is manifest (בגופני) at that ⟨specific⟩ moment. ⟨2⟩ The arc between the western horizon and the point of the solar position is like the arc—of the sphere—below the horizon ⟨between the eastern horizon⟩ and ⟨the degree that is diametrical opposite of⟩ the solar position. ⟨3⟩ If you want to know how many equinoctial hours of the night have elapsed, mark on the limb ⟨the position⟩ of the beginning of Capricorn after you have placed the star among the almucantars according to its altitude. ⟨4⟩ Turn the rete in the opposite direction of its motion [leftwards] until the degree of the sun is on the line of the western horizon. ⟨5⟩ Mark on the limb ⟨the position of the beginning of Capricorn⟩ and count how many degrees there are between the two marks. ⟨6⟩ Divide the degrees by 15 and you get the equinoctial hours that have elapsed since the beginning of the night.[4]

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[1] This calculation is also standard. See, for instance, Rodríguez-Arribas and Kozodoy 2020, Appendix 1, I at 88 (Hebrew edition) and 91 (English translation).

[2] The reason is that when the star is at, or very close to, the meridian it is difficult to detect whether the star is eastern or western and so whether the corresponding almucantar is eastern or western, so the procedure is to use a star that is far from the meridian, either before or after.

[3] See Chapter V.2.

[4] Cf. the same procedure (standard) in Ibn Ezra’s three Hebrew versions of his astrolabe text. See MSS Paris BnF heb. 1053, ff. 9a–9b (first version), Paris Bnf heb. 1043, f. 191b (second version), and Moscow Russian State Library Günzburg 937, f. 5b (third version). The second and third versions combine the calculation of the seasonal and the equinoctial hours by night and use the nocturnal arc to find them, but the first version has a section specifically dealing with the calculation of the equinoctial hour by nighttime and, like Moses’ text, does not use the nocturnal arc.

<.2> <1> ומה שכנגדה בקצה האופק המערבי היא השוקעת. <2> והמעלה שהיא עם קו חצי השמים הוא ראש הבית העשירי שהוא יתד השמים. <3> והמעלה שהיא עם יתד הארץ היא ראש הבית הרביעי שהוא הנקרא יתד הארץ ודי בזה.

<VI> שער[1] לדעת שעות הלילה.[2]

<.1> <1> כאשר לקחת גובה הככב מהככבים הידועי<ם> לך אשר בכלי שים שן הככב על דמיון גובהו בגשרים. <2> אם הוא במזרח (51b) שימהו בגשרים המזרחיים ואם הוא במערב שימהו בגשרים המערביים. <3> ואם הוא באמצע השמים הניחהו וקח ככב אחר שיהיה בצד מזרח או בצד מערב. <4> וראה מעלת השמש על אי זה מקשתי השעות נפלה ומנה שעורים מקו האופק המערבי, <5> והם השעות המעוותות שעברו מהלילה. <6> ומעלת המזלות שבקצה האופק המזרחי היא הצומחת <7> ושאר היתדות כמו שקדם.

<.2> <1> **וסבת** זה מבוארת בעצמה וזה כי להיות ששמנו מצב הכדור כפי מה שהוא בגופני בעת ההיא. <2> הנה הקשת שמהאופק המערבי עד הנקודה שהשמש בה הנה כדמיון הקשת שהוא בכדור תחת האופק <המזרחי>[3] עד מקום <נוכח>[4] השמש[5]. <3> **ואם** תרצה לדעת כמה שעות שוות עברו מהלילה סמן עם ראש גדי בתא כאשר שמת הככב על הגשרים בדמיון גובהו. <4> וסבב הרשת הפך תנועתה עד בוא מעלת השמש על קו האופק המערבי. <5> וסמן בתא ודע כמה מעלות בין שני הסימנין <6> וחלק המעלות {~~בתא ודע כמה מעלות בין שני~~}[6] [על][7] {~~ב~~}ט"ו[8] והיוצא בם הם שעות שוות שעברו מתחלת הלילה.

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[1] Marginal note, hand one: ו'.
[2] The title of this chapter is not in bold script.
[3] I introduced this term, which is essential to understand the sentence and is not in the manuscript.
[4] I introduced this term, which is essential to understand the sentence and is not in the manuscript.
[5] Final ש written in superscript.
[6] Crossed out (rightly).
[7] Interlineal correction, hand two, which replaces the letter that was crossed out (ב) in the following word.
[8] Crossed out (rightly).

⟨VI.3 What to do when there are no seasonal hour divisions on the astrolabe⟩

⟨1⟩ If the ⟨seasonal⟩ hour ⟨lines⟩ are not engraved on the astrolabe, find the value of the arc of the seasonal hour of that night from the arc of the diurnal hour as you did before.[1] ⟨2⟩ Divide the degrees that you found between the two marks by the arc of the seasonal hour. ⟨3⟩ The result is the seasonal hours of the night that have elapsed. ⟨4⟩ If there remain degrees without ⟨exact⟩ division, multiply them by 60 ⟨minutes, which is one hour⟩, divide them by the nocturnal arc of the ⟨seasonal⟩ hour. ⟨5⟩ The result is the minutes of the nocturnal hour in which you are.[2]

VII (52a) **CHAPTER: TO KNOW THE SOLAR ALTITUDE AT NOON FOR ANY DAY THAT YOU WANT AND THE DEGREE OF THE SUN AT MIDNIGHT**

⟨VII.1 The maximum altitude of the sun on the meridian by day⟩

⟨1⟩ The altitude of the sun ⟨at noon or at midnight⟩ means to know the maximum solar altitude the sun can reach that day or that night. ⟨2⟩ If you want to know this, find the degree of the sun for that day as I have showed you. ⟨3⟩ After that, mark the degree on the zodiac engraved on the rete. ⟨4⟩ Move the rete until this degree that you have marked is on the meridian line that goes through the suspensory part ⟨of the astrolabe⟩.[3] ⟨5⟩ Then mark the almucantar on which the position [of the degree] falls when it [the degree] is on the meridian. ⟨6⟩ After that, count the almucantars between the horizon and this almucantar. ⟨7⟩ The number of the degrees of the sun will be the same as the number of the almucantars if the instrument is complete, or its double if it is medial, and so on. ⟨8⟩ ⟨This is the maximum altitude⟩ that the sun can reach on the meridian that day.

⟨VII.2 The maximum altitude of the sun on the meridian by night⟩

⟨1⟩ Move the rete so that the degree that you marked crosses the lower meridian, ⟨and⟩ mark the almucantar on which the degree that is the diametrical opposite of the sun falls. ⟨2⟩ Count all the almucantars between the horizon and the almucantar you have marked. ⟨3⟩ The number of the degree ⟨which is the maximum altitude⟩ of the sun for that day at midnight will be the number of the almucantars ⟨you have counted⟩ if the instrument is complete; or twice it [this number] if the instrument is medial, and so on.[4]

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[1] See Chapter IV.7.

[2] This problem is absent in Ibn Ezra's versions of his astrolabe text.

[3] The Hebrew words *rešet* and *sevaḵah* are used in this paragraph to denote the rete of an astrolabe, another indication that Moses ben Abraham is merging different sources and consequently terminological traditions for his explanation of the astrolabe. For these terms in earlier astrolabe literature in Hebrew, see Rodríguez-Arribas 2016, 93–94, 96, and 104.

[4] This calculation is not given in any of Ibn Ezra's Hebrew versions of his astrolabe text.

<.3> <1> ואם לא היו השעות רשומות בכלי דע שעור קשת השעה המעוותת ללילה ההיא מקשת השעה היומית כמו שקדם. <2> וחלק המעלות שלקחת מבין שני הסימנין על קשת השעה המעוותת <3> והיוצא הם שעות מעוותות שעברו מהלילה. <4> ואם נשארו מעלות שלא נחלקו הכה אותם בס' ותחלק העולה בקשת השעה הליליית. <5> ויצאו לך דקי השעה שאתה עומד בה בלילה.

<VII> (52a) שער[1] לדעת גובה[2] השמש בחצי היום בכל יום שנרצה וידיעת מעלת השמש בחצי הלילה.

<.1> <1> והכונה הנה בגובה השמש הוא שנדע גובה השמש באותו היום או הלילה באי זו מעלה היותר גבוהה שיוכל לעלות השמש בה. <2> אם רצית לדעת זה דע מעלת השמש באותו היום כמו שהראיתיך. <3> ואחר כך רשום אותו המעלה בעגול המזלות המונח בשבכה[3]. <4> עוד תניע הרשת עד שתחנה אותה המעלה הרשומה על קו חצי היום העובר ממקום התלייה. <5> אחר כן רשום אותו הגשר שתפול עליו אותה הנקודה בהיותה בקו חצי השמים. <6> אחר כן מנה הגשרים שמהאופק עד אותו הגשר, <7> וכמספר אותם הגשרים כך הוא מספר מעלות השמש, אם היה הכלי שלם או בכפלם אם היה חצי וזולתו, <8> שיוכל לעלות השמש בחצי היום באותו היום.

<.2> <1> וכשתניע הרשת עד שתעבור אותה המעלה הרשומה ביתד הארץ, רשום הגשר שיפול בו נכח מעלת השמש. <2> ומנה מן האופק כל הגשרים עד הגשר הרשום, <3> וכמספר אותם הגשרים יהיה מעלת השמש בחצי הלילה של אותו היום אם הכלי שלם או בכפלם אם הכלי חצי וזולת זה.

[1] Marginal note, hand one: ז'.
[2] The title of this chapter is not in bold script.
[3] Hand seven marked this word with two dots; it is clearly not an indication of mistake.

⟨VII.3 What to do when the instrument is not complete and the degree of the sun falls between two almucantars: Method one⟩[1]

⟨1⟩ If it is not ⟨so⟩—that is, the instrument is not complete—and the degree of the sun has fallen between two almucantars [*A1* and *A2*], mark on the limb ⟨the position of⟩ the beginning of Capricorn; ⟨2⟩ this is called the intermediate mark [*M3*]. ⟨3⟩ Turn again the rete in the opposite direction of its ⟨natural⟩ motion [leftwards] until the degree of the zodiac coincides with the previous almucantar [*A1*]. ⟨4⟩ Mark there on the limb ⟨the position of⟩ the beginning of Capricorn [*M1*]. ⟨5⟩ ⟨Do the same for the following almucantar [*A2*] and mark on the limb the position of the beginning of Capricorn [*M2*]⟩. ⟨6⟩ Then observe the number ⟨of the degrees⟩ between the two marks [*M1* and *M2*] and also between the intermediate [*M3*] and the first mark⟨s⟩ [*M1*]. ⟨7⟩ Find the ratio of ⟨the degrees⟩ between the intermediate and the first ⟨marks⟩ [*M3*-*M1*] (52b) to ⟨the degrees⟩ between the two ⟨other⟩ marks [*M2*-*M1*]. ⟨8⟩ Apply the value of this ratio to the number ⟨of degrees⟩ separating the two almucantars [*A2*-*A1*] and add it to the number ⟨of degrees⟩ written on the ⟨previous⟩ almucantar [*A1*].[2] ⟨9⟩ The ⟨result of the⟩ addition is the number of the solar ⟨maximum⟩ altitude at noon that day.[3]

⟨VII.3a Demonstration of method one⟩

⟨1⟩ The reason is that when the sun rises in one degree any day of the year, for that day and its ⟨corresponding⟩ night the sphere carries the sun in this degree of the circle parallel to the equator until it returns to the same degree. ⟨2⟩ When the sun crosses the ⟨upper⟩ meridian, which is directly above our heads [i.e., the zenith], it is the highest it can be, then it is the midday of that day. ⟨3⟩ But when the sun crosses the meridian that is below the horizon, then it is midnight; this is because the instrument represents the sphere. ⟨4⟩ For this, when we move the degree of the sun on ⟨the rete of⟩ the instrument, it is as if the sphere in our hands moved, ⟨5⟩ when the degree of the sun crosses the meridian, it is as if the sun crossed the meridian; ⟨6⟩ and when it crosses the angle of the earth [the lower meridian], it is as if the sun crossed the meridian that is below the horizon.[4]

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[1] This section, as the previous provision of solutions for hypothetical situations such as "what to do when ...," clearly fits with Ibn Ezra's distinctive concern to provide solutions for every possible situation in which one has to use the astrolabe and a component, a feature, or a parameter, essential for the calculation, is missing in the instrument. See Rodríguez-Arribas 2014, 242–244 and 247. This is certainly a problem that Moses ben Abraham shared with Ibn Ezra or took from him and so he is realistic about the availability and about the actual state of the instruments that existed and were circulating in Ottoman lands among Jews interested in astronomy/astrology.

[2] Some astrolabes display numbered almucantars but others do not.

[3] This method (interpolating the value), very frequently found in Ibn Ezra's texts for other calculations, is referred to for the calculation of the meridian altitude of the sun only in Ibn Ezra's second version (MS Paris BnF heb. 1045, ff. 189b–190a), see Appendix 6. Ibn Ezra considers it approximate because of the way of calculating.

[4] I consider the use of *yeted ha-areṣ* to denote the lower meridian as an indication of Moses ben Abraham's involvement with astrology (as shown also by his translation of the astrological text about eclipses), but also evidence of the overlapping of certain terms in the astronomical and astrological uses of astrolabes (in Hebrew and in other medieval languages). There were Hebrew terms to explicitly distinguish between the meridians (the upper and the lower), i.e., the great circle crossing the zenith of the horizon and the pole of the earth, and their corresponding equivalents in the horoscope (the midheaven and the angle of the earth, i.e., the cusps of the tenth and the fourth houses respectively), but they were not systematically used. For the same overlap in Joseph ben Solomon Ṭaiṭaṣaq's treatise on the construction of an astrolabe, see Rodríguez-Arribas and Kozodoy 2020, 91 n. 184.

<3.> <1> אמנם אם לא, רצו<ני>[1] בכלי שלם, ונפלה מעלת השמש בין שני גשרי<ם> סמן סימן בתא עם ראש גדי, <2> ויקרא סימן אמצעי. <3> עוד סבב הרשת להפך תנועתה עד שתמשש מעלה מהמזלות את גשר שעבר, <4> וסמן שם ראש גדי בתא. <5> <...>.[2] <6> וראה מה שבין שני הסימנין גם מה שבין הסימן האמצעי והראשון. <7> וראה ערך מה שבין האמצעי והראשון (52b) למה שבין שני הסימנין, <8> וקח מן המספר שבין גשר לגשר כשעור[3] היחס ההוא והוסף אותו על מספר הכתוב בגשר. <9> והעולה יהיה מספר גובה השמש בחצי היום ההוא.

<3א.> <1> הסבה מפני שבכל מעלה שיעלה השמש באי זה יום מהשנה הנה באותו היום עם הלילה שלו יסוב הגלגל את השמש באותה המעלה [ע]גולה[4] נכחית למשוה עד שישוב באותה המעלה. <2> וכשיעבור השמש בחצי השמים שבנכח ראשנו הוא היותר גבוה שיוכל השמש[5] לעלות ואז הוא חצי היום באותו היום. <3> וכשיעבור השמש בחצי השמים שתחת האופק אז הוא חצי הלילה {~~הו~~}[6] מפני שהכלי הוא במקום הגלגל. <4> לזה כשהנענו מעלת השמש בכלי כאלו הכדור בידינו מתנועע, <5> וכשעברה מעלת השמש בקו חצי היום כאלו עבר השמש בחצי השמים {~~שתחת~~},[7] <6> וכשעבר ביתד הארץ כאלו עבר השמש בחצי השמים שתחת האופק.

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[1] There is no indication here of an abbreviation.
[2] A sentence is missing here to make sense of the explanation.
[3] ר written in superscript.
[4] Interlineal correction, hand two, that corrects the original letter (ס) that has been crossed out (rightly).
[5] Hand seven marked this word with two dots and the following with one to indicate an exchange in their order, so that one reads לעלות השמש rather than השמש לעלות.
[6] Crossed out (rightly).
[7] Crossed out (rightly).

⟨7⟩ This is apparent when you conceptualize (תדמה) it properly, and this is enough.

⟨VII.4 Method two⟩

⟨1⟩ There is another method, which is approximate and it is used when you do not have the ⟨latitude⟩ plate of your location in your astrolabe. ⟨2⟩ It consists of checking that the altitude [of the sun] increases until it reaches its maximum that day; this is the point of midday. ⟨3⟩ You need this method in the following chapter.[1]

VIII CHAPTER: TO KNOW THE LATITUDE AND LONGITUDE OF ANY PLACE

⟨VIII.1 The latitude for any oblique horizon with the meridian altitude of the sun at the equinoxes⟩

⟨1⟩ The meaning of the latitude of a place is the distance of its zenith from the circle of the equator measured on the circle that crosses the pole of the world and the pole of the horizon. ⟨2⟩ If you want this, find the altitude of the sun at noon as we did before. ⟨3⟩ If the sun is at the beginning of Aries or Libra, subtract the altitude you have taken ⟨from 90⟩. (53a) ⟨4⟩ The remainder is the latitude of the place.[2] ⟨5⟩ The reason for this is that the altitude of the sun above the earth on the horizon of the equator is 90 degrees when the sun is at the beginning of Aries [i.e., at the equinoxes].[3]

⟨6⟩ As regards the oblique horizons, whatever be the inclination of the southern pole,[4] you subtract from 90 degrees the ⟨meridian⟩ altitude ⟨of the sun⟩ at the beginning of Aries. ⟨7⟩ In this way if one knows the maximum solar altitude at the beginning of Aries and subtract it from 90, the remainder is the inclination of the southern[5] pole from the horizon. ⟨8⟩ The inclination of the southern pole ⟨from the horizon⟩, which the circle of the horizon of the equator crosses, is like the distance between the pole of the horizon and the pole of the equator.[6]

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[1] There is no need to say that this method is not accurate. Moses is facing here another possible circumstance: one is calculating the meridian altitude of the sun on the local horizon when there is no latitude plate for one's horizon.

[2] A is the altitude, L is the latitude, so $L = 90-A$.

[3] Cf. the third (of four) methods to find the latitude of a plate (subtracting from 90º the altitude of the vernal equinox, i.e., the meridian altitude of the sun at the beginning of Aries or Libra on the local horizon) in Ibn Ezra's first and third versions of his astrolabe text; see MSS Paris BnF heb. 1053, ff. 4b–5a, and Moscow Russian State Library Günzburg 937, ff. 4a–4b, respectively. Of course, the ways to find the latitude of an unidentified plate (which represents a local horizon) and the actual latitude of a local horizon are identical.

[4] Lit: "the inclination of the southern pole with respect to the oblique horizons."

[5] It is unusual that Moses ben Abraham uses the southern rather than the northern pole.

[6] For this and the following calculations (VIII.1–5) in Ibn Ezra's astrolabe texts in Hebrew (finding the local latitude using the local meridian altitude of the sun at the solstices and equinoxes), see MSS Paris BnF heb. 1053, ff. 13b–14a (first version), BnF heb.1045, f. 192a (second version), and Moscow Russian State Library Günzburg 937, ff. 4b–5a (third version).

<7> וזה מבואר כשתדמה אותו היטב ודי בו.

<.4> <1> **ועוד** דרך אחרת קרוביית והוא אם אין לך לוח ארצך בכלי שלך. <2> והוא שתסתכל שיהיה הגובה הולך ומוסיף עד תכלית גובהו ביום ההוא וזו היא נקודה[1] חצי היום. <3> וזה הדרך תצטרך אותו בשער {ש}הבא[2].

<VIII> שער[3] לדעת מרחבי[4] המקומות וארכם.

<.1> <1> והכונה ברוחב המקום הוא מרחק נכח ראשו מעגולת המשוה המשוער בעגול העובר על קטב העולם וקטב האופק. <2> אם רצית זה דע גובה השמש בחצי היום כפי מה שקדם. <3> ואם השמש בראש טלה או מאזנים אז תחסר הגובה שלקחת <מצ'>[5] <4> (53a) והנשאר הוא רחב המקום. <5> וסבת זה כי באופק השווי יהיה גובה השמש על הארץ צ' מעלות בהיותו בראש טלה.

<6> והאופקים הנוטים כל מה שישפל מהם הקוטב הדרומי תחסר הגובה שבראש טלה מצ' מעלות. <7> ולכן כאשר נדע תכלית גובה השמש בהיותו בראש טלה ונגרעהו מצ', ישאר מה שישפל הקוטב הדרומי מן האופק. <8> וכשעור מה שישפל הקוטב הדרומי שתעבור עליו עגולת אופק השווי יתרחק קוטב האופק מקוטב אופק השווי.

[1] It should be נקודת.
[2] Crossed out (rightly).
[3] Marginal note, hand one: ח.
[4] The title of this chapter is not in bold script.
[5] I introduced the word that is missing to complete the meaning.

⟨VIII.2 The latitude when the sun is at the winter solstice⟩

⟨1⟩ If you take the maximum solar altitude at the beginning of Capricorn, subtract from 90 the [solar] declination, which is according to Zarqali 23 degrees and 33 minutes, and according to Ptolemy 23 degrees and 51 minutes.[1] ⟨2⟩ If one subtracts from the remainder the solar altitude at the beginning of Capricorn, this remainder will be the latitude of the place (רוחב).[2] ⟨3⟩ The reason for subtracting the ⟨solar⟩ declination from 90 is that this number [the solar declination] is the difference in the ⟨local⟩ horizon between the altitude of the sun at the beginning of Capricorn and at the beginning of Aries.

⟨VIII.3 The latitude when the sun is at the summer solstice⟩

⟨1⟩ If you take the maximum solar altitude at the beginning of Cancer, add the declination to 90 and subtract the ⟨maximum⟩ solar altitude at the beginning of Cancer from the total; the remainder is the latitude of the place. ⟨2⟩ The reason is that the distance between the southern pole and the beginning of Cancer is approximately 114 degrees.[3] ⟨3⟩ This is the ⟨meridian⟩ altitude of the beginning of Aries on the horizon of the equator plus the declination of the beginning of Cancer. ⟨4⟩ This is ⟨also⟩ the distance between the beginning of Cancer and the horizon of the equator in the southern part ⟨of the sphere⟩.

⟨5⟩ According to this (אם כן), the latitude of the place is the difference between the ⟨maximum⟩ altitude of the beginning of Cancer on the oblique horizon and the distance between the point of the southern horizon and the straight horizon.[4] ⟨6⟩ For this, when we subtract the maximum ⟨solar⟩ altitude at the beginning of Cancer from 114 degrees, the remainder is the latitude of the place. ⟨7⟩ Or ⟨if⟩ we subtract the maximum altitude from 90, the remainder is the distance between (53b) the zenith and the circle of Cancer. ⟨8⟩ Then we add the ⟨solar⟩ declination to the remainder and the result is the latitude of the place.[5]

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[1] As regards the value 23;51° in Ptolemy, see *Almagest*, I, 12. The value attributed to Azarquiel but found in the Toledan Tables is 23;33,30°; see Toomer 1968, 30. For the value of 23;30º found in the Almanac of Zarqali, see Millás Vallicrosa 1943–50, 174. Abraham Ibn Ezra uses in his three astrolabes treatises a rounded off value of this inclination (24º), just as Moses does below (VIII.2, 2).

[2] $L = (90-D) - A$, where D is the solar declination when the sun is at the beginning of Capricorn (the winter solstice).

[3] I.e., 90 + 24 degrees. Notice the rounded-off value of the inclination of the ecliptic in this demonstration, in spite of the very accurate values he just referred to in the previous section (VIII.2, 1).

[4] $L = (90 + D) - A$, where D is the solar declination when the sun is at the beginning of Cancer (the summer solstice).

[5] $L = (90 \mp D) - A$, where D is the solar declination. Again, a clear indication that the author feels completely at ease dealing with these calculations and is eager to show how the same result can be achieved in different ways, just like A. Ibn Ezra does in his astrolabes treatises. See Rodriguez-Arribas 2014, 227 and 254.

<2.> <1> ואם לקחת תכלית גובה השמש בהיותו בראש גדי תגרע שעור הנטייה מצ', שהיא לזרקלי כ"ג מעלות ול"ג דקי<ם> ולבטלמיו<ס> כ"ג מעלות נ"א דקים, <2> ומהנשאר אם חסר גובה השמש בהיותו בראש גדי והנשאר הוא רוחב המקום. <3> וסבת גורעינו הנטייה מצ' להיות שבשעור ההוא יחסר גובה השמש באופק בהיותו בראש גדי מהיותו בראש טלה.

<3.> <1> ואם לקחת תכלית גובה השמש בהיותו בראש סרטן הוסף שעור הנטייה על צ' וגרע מהמקובץ גובה השמש בראש סרטן והנשאר הוא רחב המקום. <2> והסבה כי להיות שמרחק הקוטב הדרומי מראש סרטן הוא קי"ד מעלות בקירוב, <3> שהוא שעור גובה ראש טלה באופק השווי עם נטיית ראש סרטן מקובצים. <4> והוא מרחק ראש סרטן מאופק השווי שמצד הדרומי.
<5> הנה א<ם> כ<ן> כשעור מרחב המקום יהיה גובה ראש סרטן באופק הנוטה רחוק מנקודת האופק הדרומי פחות ממה שהוא באופק השווי {כשעור מרחב המקום}[1]. <6> ולזה כשנסיר תכלית גובה ראש סרטן מקי"ד מעלות יהיה הנשאר רוחב המקום, <7> או נסיר הגובה מצ' וישאר מה שבין (53b) נכח הראש ועגול ראש סרטן <8> ונוסיף על הנשאר שעור הנטייה והוא יהיה רוחב המקום.

[1] These words are redundant, the scribe got confused and repeated the end of a line placed two lines before.

⟨VIII.4 The latitude when the sun is in any other degree of the zodiac: Method one⟩

⟨1⟩ Regarding their difference you do as you did regarding the beginning of Cancer and the beginning of Capricorn. ⟨2⟩ If you know the ⟨meridian⟩ solar altitude when it [the sun] is in a degree different from these [i.e., different from either of the two solstices or the equinoxes], find the declination of this degree. ⟨3⟩ Then observe if it, i.e., the degree of the sun, is northern or southern. ⟨4⟩ If it is southern, subtract that ⟨solar⟩ declination from 90. ⟨5⟩ If it is northern, add the ⟨solar⟩ declination to 90. ⟨6⟩ Subtract the altitude of the sun on the meridian from the result; ⟨7⟩ the remainder is the latitude of that place.

⟨VIII.5 The latitude when the sun is in any other degree of the zodiac: Method two⟩

⟨1⟩ Another general method: find the declination of the ⟨solar⟩ degree: if it is northern, subtract it from the ⟨meridian⟩ solar altitude. ⟨2⟩ If it is southern, add it to the ⟨meridian⟩ solar altitude. ⟨3⟩ The result you get is the altitude on the horizon of the beginning of Aries. ⟨4⟩ Subtract it from 90 and the remainder is the latitude of the place.

⟨VIII.6 How⟩ to calculate the longitude of ⟨one's⟩ location ⟨using lunar eclipses and an astrolabe⟩[1]

⟨1⟩ The longitude of the place is its distance either from the eastern or from the western extremity of the inhabited world.[2] ⟨2⟩ The exact method in use is finding the hour of the lunar eclipse in any of the tables arranged for another city ⟨in which the eclipse takes place at another moment⟩.[3] ⟨3⟩ Find the moment of the night at which the eclipse starts there [in that city]. ⟨4⟩ Then find on the astrolabe the hour of the night at which the eclipse starts in your location.

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[1] This calculation of the longitude using lunar eclipses and an astrolabe (VIII.6), and that using the conjunction of the moon or a planet with a fixed star (VIII.7) are not found in Ibn Ezra's astrolabe texts. Montalto explains the calculations using the solar eclipse by daytime and the lunar one by nighttime and gives a practical example for the first case (by daytime with an astrolabe); see MS Paris BnF heb. 1047, f. 88a.

[2] The prime meridian for geographical longitude in Ptolemy and in many tables of the Middle Ages passed through the Canary Island (the Fortunate Islands). See for instance Chabás Bergón and Goldstein 2014, 365. For a description of Ptolemy's geography, see Berggren and Jones 2000. Moses ben Abraham does not give any information that allows us to establish his specific meridian.

[3] If the eclipse takes place at the same time in both cities, then the logitude is the same.

<4.> <1> וכדרך שעשית בראש סרטן ובראש גדי תעשה במה שביניהם. <2> וזה שאם ידעת גובה השמש בהיותו במעלה אחרת דע נטיית המעלה ההיא. <3> וראה אם היא רצו<ני> המעלה שהשמש בה צפונית או דרומית. <4> ואם היא דרומית תגרע הנטייה ההיא מצ', <5> ואם צפונית תוסיף הנטייה על צ'. <6> ותוציא מאשר בידך שעור גובה השמש בחצי היום, <7> ויהיה הנשאר מרחב המקום ההוא.

<5.> <1> דרך אחרת ג<ם> כ<ן> כוללת: דע שעור נטיית המעלה ואם היא צפונית תגרעה מגובה השמש, <2> ואם דרומית תוסיפה על גובה השמש. <3> וההווה בידך הוא גובה ראש טלה על האופק, <4> גרעהו מצ' וישאר רוחב המקום.

<6> ולדעת אורך המקום.

<1> הנה אורך המקום הוא אם מרחקו מקצה מזרח היישוב או מערב. <2> והנה הדרך המדוקדק שישתמשו בו הוא שתדע השעה שתפול בה לקות ירחי מאי זה ממיני הלוחות שסודרו על מדינה מה אחרת. <3> ודע הרגע מהלילה שיכנס הלקות שם <4> ודע בכלי ההבטה השעה מהלילה שיהיה בה תחלת הלקות במקומך.

⟨5⟩ Observe if the eclipse takes place in your location prior ⟨to the other location⟩. ⟨6⟩ Then your location is as much east as the number of the hours separating ⟨your eclipse from the eclipse in the other city⟩. ⟨7⟩ If it [your eclipse] takes place later, it [your location] is more western ⟨than the other according to the same difference of the hours⟩. ⟨8⟩ Take 15 degrees for every hour and one degree for every 4 minutes of an hour.[1] ⟨9⟩ This is the difference in longitude between the two locations. ⟨10⟩ Know that the difference of the hours that you find when you observe the time of the eclipse indicates the time of the eclipse after midday. ⟨11⟩ It is the same for an eclipse calculated according to tables, for the rising and the setting change in every location depending on the latitude, even if (54a) they share the same longitude. ⟨12⟩ However, the moment of midday is the same for all the cities with the same longitude; ⟨13⟩ it is the same for the length from midday to midday ⟨for these cities⟩.

⟨VIII.7 How to find the longitude using the conjunction of the moon or a planet with one of the fixed stars⟩[2]

⟨1⟩ One can find the longitude using the conjunction of the moon with one of the fixed stars close to the ecliptic, like the star called the Heart of Leo [*α Leonis*, i.e., Regulus] or the star called *Simaq al-ʿAzʾal* [*α Virginis*, i.e., Spica].[3] ⟨2⟩ It is the same for the conjunction of one of the planets with one of the fixed stars. ⟨3⟩ We have to find the conjuntion of the planet ⟨and the star⟩ in the tables and look ⟨for it⟩ in our horizon at the moment of their conjunction. ⟨4⟩ We find the difference between the two places from the fractions of an hour, although it is hard to ascertain this with accuracy.[4]

⟨VIII.8 The latitude using the fixed stars⟩

⟨1⟩ There are also methods to find the latitude of the city using the fixed stars, either the stars that rise and set or the stars that do not set at all [i.e., the circumpolar stars]. ⟨2⟩ You have to look at the star at the northern pole that does not set below the earth [i.e., the horizon] at all. ⟨3⟩ Find the limit of its maximum altitude above the horizon and the limit of its minimum altitude. ⟨4⟩ Look how many degrees there are between the maximum and the minimum altitude⟨s⟩. ⟨5⟩ Take its half and add it to the minimum altitude of the star. ⟨6⟩ The result is the altitude of the northern pole above the horizon. ⟨7⟩ This is the latitude of the location.[5]

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[1] As we have previously said, the sun moves one degree every four minutes in its daily motion.

[2] This calculation is in neither Ibn Ezra’s astrolabe texts nor Montalto’s text.

[3] These are the names of two stars close to the ecliptic. The Arabic name of the second is السِماَك الأَعْزَل (“the unarmed *Simāk*”), the meaning of *Simāk* is not sure, see Kunitzsch 1959, 146–147 (no. 66); and Kunitzsch and Smart 2006, 59–60.

[4] Here we find a concern with accuracy of the calculation that was characteristic of several authors (A. Ibn Ezra among them as previously indicated) and indicates how aware they were of the limitations of their instruments, even in the 15th/16th centuries when excellent workshops of astronomical instruments had been established in different parts of Europe (Paris, Leuven, Nürnberg, and elsewhere ...). In this specific calculation, which involves the positions of planets and fixed stars, accuracy is even more difficult to attain due to the slow motions of the planets.

[5] This calculation is found in two of Ibn Ezra’s Hebrew texts on the astrolabe; see MSS Paris BnF heb. 1053, f. 14a (first version) and BnF heb. 1045, f. 192b (second version); there is nothing about this calculation in the third version.

<5> וראה אם הלקות קדם במקומך. <6> הנה מקומך יותר מזרחי בשעור שעות הקדימה, <7> ואם נתאחר הוא יותר מערבי. <8> קח לכל שעה ט"ו מעלות ולכל ד' דקים משעה מעלה, <9> והוא ההפרש שבין שני המקומות באורך. <10> ודע כי השעות שתראה מההפרש הוא כשתראה שעת הלקות כמה שעות הוא אחר חצי היום. <11> וכן בלקות שהוצאת מהלוחות מפני שהזריחה והשקיעה תתחלף במקומות מצד הרוחב ואפי<לו> (54a) שיהיו משותפים באורך; <12> אבל רגע חצי {הרוחב}[1] היום תהיה לכל המדינות המשותפות באורך; <13> כך השעור שמחצי היום לחצי היום.

<.7> <1> **ויתכן** לדעת האורך מצד חבור הירח לא<חד>[2] מהככבי<ם> הקיימים הקרובים לאזור המזלות כמו הככב הנקרא לב האריה והככב הנקרא סמק אלעזאל[3]. <2> וכן עם חבור אחד מהרצי<ם> עם חבור ככב אחד[4] מהקיימים. <3> וזה שנדע חבור הככב ההוא בלוחות ונביט באופקינו ג<ם> כ<ן> עת חבורם. <5> ונדע כמה בין שני המקומות מצד חלקי השעות אך קשה העמידה על דקדוק זה.

<.8> <1> **עוד** יש דרכי<ם> לדעת רוחב העיר והם מצד הככבים הקיימים, אם מצד הככבים שיש להם זריחה ושקיעה, אם מצד הככבים אשר לא ישקעו כלל. <2> וזה שתביט אל ככב שאצל הקטב הצפוני שלא ישקע[5] מעל הארץ כלל, <3> ותמצא תכלית גובהו הגדול על האופק עוד תמצא תכלית גובהו היותר קטן. <4> וראה מעלות שבין הגובה הגדול לקטן <5> וקח חצים והוסיפם על גובה הככב היותר קטן. <6> והעולה יהיה שעור גובה הקוטב הצפוני על האופק <7> וכשעורו הוא מרחב המקום.

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[1] Hand six marked this word as a mistake (rightly).
[2] There is no indication here of an abbreviation.
[3] The two words of סמק אלעזאל (an Arabic name in Hebrew characters) are marked on top.
[4] Written אחר.
[5] An unidentified hand wrote above the ש (which might be indicated as wrong) what looks to be a tiny ה. This correction does not make sense.

⟨8⟩ You need to know that this ⟨circumpolar⟩ star must necessarily be at the beginning of the night either around (סמוך ל) its maximum altitude and eastern or ⟨around⟩ its minimum altitude and western. ⟨9⟩ If it is not so, when this is about to happen, ⟨i.e.⟩ when it [the circumpolar star] is about to reach its maximum or its minimum altitude, you need to persevere more, I mean many nights, until this happens. ⟨10⟩ Even if the star is close to its maximum or its minimum altitude at the beginning of the night, this must happen in one of those long nights that are longer than 12 hours,[1] but you can finish ⟨your⟩ search (54b) ⟨just⟩ in one night.[2]

⟨VIII.8a The latitude using a fixed star that rises or sets on the horizon⟩

⟨1⟩ If you want to know this from one of the fixed stars that rise and set on the horizon and the star crosses in its rising the meridian that is south for us, we take its maximum altitude and find its declination with respect to the equator. ⟨2⟩ If it is southern, we add it to the ⟨meridian⟩ altitude; if it is northern, we subtract it from it [the meridian altitude]. ⟨3⟩ The remainder is the altitude of the beginning of Aries. ⟨4⟩ We subtract it from 90 and we get the latitude of the location.[3]

⟨VIII.8b The latitude using a fixed star that has no declination with respect to the equator⟩

⟨1⟩ If the star does not have declination with respect to the equator, its maximum altitude is the altitude of the beginning of Aries. ⟨2⟩ However, if the star crosses in its rising northward for us, it crosses between the pole of the horizon and the pole of the equator. ⟨3⟩ Then take its maximum altitude and subtract it from 90; ⟨4⟩ the remainder is the distance between the point of the zenith and the point west of the star when it is on the meridian. ⟨5⟩ So we subtract this remainder from the value of the ⟨solar⟩ declination and the result is the distance [latitude] of the location, and this is enough.

[1] This means that the observation must be performed around the winter solstice, when the nights are longer than the days. This could be any night between the autumn equinox and the spring equinox but trying to remain separate from the equinoxes when nights and days have the same length (12 hours).

[2] All these procedures try to attain as much precision as possible.

[3] Compare this procedure with that presented in sections VIII.4 and VIII.5 (methods one and two, respectively, to find the latitude of the location when the sun is in any degree of the zodiac except for the solstices and the equinoxes).

<8> וצריך שתדע שצריך שיהיה הככב הזה בתחלת הלילה סמוך לגובהו היותר גדול ומזרחי או הקטן ומערבי. <9> ואם לא רצו<ני> שכאשר היה כן הנה הוא עתיד עדין לבוא אל גובהו או שפלותו תצטרך בזה אל יגע רב רצו<ני> משקידה בלילות רבות, <10> ואף אם הככב קרוב לתכלית גובהו או שפלותו בתחלת הלילה צריך שיהיה מהלילות הארוכות[1] הנוספות על י"ב שעות ואז אפש<ר> שתשלם לך החקירה מזה בלילה אחת. (54b)

<8א.> <1> **ואם** תרצה לדעת זה מצד אחד הככבים הקיימי<ם> שיש להם זריחה ושקיעה על האופק, אם הוא עובר למעלתו בחצי השמים דרומי לנו נקח גובהו היותר גדול ונדע נטייתו מהמשוה. <2> ואם היא דרומית נוסיפנה על הגובה ואם היא צפונית נגרעה ממנו, <3> והנשאר הוא גובה ראש טלה. <4> נחסרהו מצ' ויצא רוחב המקום.

<8ב.> <1> ואם הככב בלתי נוטה מהמשוה הנה גובהו היותר גדול הוא גובה ראש טלה. <2> אולם אם הככב עובר במעלתו צפוני לנו כי אז יעבור בין קוטב האופק וקטב המשוה. <3> הנה תקח גובהו היותר גדול וחסרנו[2] מצ', <4> והנשאר הנה הוא השעור שבין נקודת נכח הראש לנקודת מעבר הככב בחצי השמים. <5> ולזה נגרע זה הנשאר משעור הנטייה וישאר מרחק המקום ודי בזה.

[1] ת written in superscript.
[2] It should be ותחסרנו.

IX CHAPTER: TO KNOW FOR ANY DAY THE POSITION OF THE SUN IN THE ZODIAC BY ANOTHER METHOD [METHOD ONE][1]

⟨IX.1 The position of the sun in the zodiac by method one⟩

⟨1⟩ If you want to know the degree of the sun with truth, you need to know in which quarter of the year you are and also ⟨to use⟩ a complete instrument. ⟨2⟩ When you want to know the solar position, observe close to midday, and do not move until the sun ⟨starts to⟩ incline to the west, that is, until the degrees of [its] altitude start to decrease. ⟨3⟩ After you know the solar altitude on the meridian, check in which quarter of the year ⟨you are⟩.[2]

⟨IX.2 The path of the sun in the zodiac and the four quarters of the year⟩

⟨1⟩ The sun in this our time goes from March 10th to June 12th through the signs of Aries, Taurus, and Gemini, which is the first quarter [of the year, i.e., the spring]. ⟨2⟩ During this time the sun goes up in the north, that is, it comes closer in latitude ⟨to us, in the north⟩. ⟨3⟩ From June 13th (55a) to September 14th it passes through the signs of Cancer, Leo, and Virgo, which is the second quarter [i.e., the summer]. ⟨4⟩ During this time the sun goes down in the north. ⟨5⟩ From September [15th][3] to December 12th it passes through the signs of Libra, Scorpio, and Sagittarius. ⟨6⟩ This is the third quarter and ⟨during this time⟩ the balance of the sun[4] goes up in the south [i.e., it is the autumn]. ⟨7⟩ From December [13th][5] to March [9th][6] it passes through the signs of Capricorn, Aquarius, and Pisces. ⟨8⟩ This is the fourth of the quarters and ⟨during this time⟩ the sun goes down in the south [i.e., it is the winter].[7]

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[1] Method two was explained at the beginning of the treatise, see Chapter II.2. This first method to calculate the position of the sun with accuracy (IX.1–4) is also in Ibn Ezra's treatises; see MSS Paris BnF heb. 1053, ff. 7b–8a and BnF heb. 1045, f. 189b.

[2] This implies the season of the year, which is related to the position of the sun. Section IX.1 follows the second version of Abraham Ibn Ezra's astrolabe text, see MS Paris BnF heb. 1045, f. 189b: ואם ידעת רוחב המקום שאתה בו, והטעם כמה הוא מקומך רחוק מקו השוה, ויש לך לוח בכלי הנחשת על רוחב המקום תוכל לדעת מקום השמש באמת אם היה לך כלי נחשת שלם, שתסתכל קרוב מחצי היום ולא תזוז עד שיטה השמש לצד מערב. והטעם עד שתראם שיחלו מעלות גובה השמש לחסור כי מהבקר עד חצי היום היא התוספת ואחר כן המגרעת; וכאשר תדע כמה גובה השמש בחצי היום הסתכל באי זה רביעית מהשנה הוא היום שתבקש.

[3] "15th" is my correction of "14th," written in the manuscript, because of what is said in Chapter IX.2 ⟨3⟩ (and assuming this number is right).

[4] If I understood it correctly, this is an interesting image of the equinoxes as the balances of the year, when the two pans of the balance are levelled at the moment of the equinoxes.

[5] "13th" is my correction of "11th," written in the manuscript, because of what is said in Chapter IX.2 ⟨5⟩.

[6] "9th" is my correction of "10th," written in the manuscript, because of what is said in Chapters IX.2 ⟨1⟩ and IX.3 ⟨3⟩.

[7] Ibn Ezra also refers to the months of the year in the second version of his astrolabe text (MS Paris BnF heb. 1045, f. 189b, composed in Verona in 1146) but does not mention any days and so does not give the specific dates of the solstices and equinoxes as Moses does, but refers to the dates of the equinoxes (March 14 and September 16) on f. 192a. Ibn Ezra's first version (composed in Lucca in 1146) gives March 14 and September 16 as the dates of the equinoxes (see MS Paris BnF heb. 1053, f. 13b), while the third version (composed in Béziers in 1148) gives March 15 and September 16 (see MS Moscow Russian State Library Günzburg 937, f. 3a). Montalto refers to the spring equinox as March 13 (see MS Paris BnF heb. 1047, f. 84b).

<IX> **שער**[1] **לדעת מקום** השמש בכל יום מגלגל המזלות בדרך אחרת.

<.1> <1> הנה לזה אתה צריך לדעת באי זה מרבעי השנה אתה עומד[2] וצריך שיהיה הכלי שלם אם תרצה לדעת מעלת השמש באמת. <2> וכאשר תרצה לדעת מקום השמש תסתכל קרוב מחצי היום ולא תזוז עד שיטה השמש לפאת מערב והטעם עד שיחלו מעלות הגובה לחסור. <3> וכאשר תדע גובה השמש בחצי היום תסתכל באי זה רביעית מהשנה.

<.2> <1> וזה כי מפני שהשמש בזמנינו זה ילך מי' לחדש מרטי עד י"ב לייאוניו במזלות טלה שור תאומים שהוא הרביע הא', <2> ויהיה השמש עולה בצפון והטעם מוסיף להתקרב ברוחב. <3> ומי"ג לייאוניו (55a) עד י"ד לשיטברי ילך במזלות סרטן אריה בתולה שהוא הרביע השני, <4> {וילך}[3] ויהיה השמש יורד בצפון. <5> ומי"ד[4] לשיטיברי עד י"ב לדיקיברי הולך במזלות מאזנים עקרב קשת, <6> והוא הרביע השליש<י>[5] ואז יהיה מאזני[6] השמש עולה בדרום. <7> ומי"א[7] לדקיברי עד י'[8] למרטי ילך במזלות גדי דלי דגים, <8> והוא הרביע הרביעי ואז יהיה השמש יורד בדרום.

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[1] Marginal note, hand one: ט'.
[2] ד written in superscript.
[3] Crossed out (rightly).
[4] It should be ומט"ו because of what is said in Chapter IX.2 ⟨3⟩.
[5] There is no indication here of an abbreviation.
[6] Hand six marked the word as a mistake, but it is not clear whether it is. Moses might have given an image of the solar path as a balance that twice a year, at the equinoxes, is perfectly balanced and all other days inclines northward or southward. However, this remains debatable for the image is not attested anywhere else.
[7] It should be י"ג as in IX.2 ⟨5⟩ and IX.3 ⟨3⟩.
[8] It should be ט' according to IX.2 ⟨1⟩ and IX.3 ⟨3⟩.

⟨IX.3 Using the quarters to place the position of the sun among the almucantars⟩

⟨1⟩ When you know the quarter of the year, count the almucantars from the first horizon line [i.e., the first almucantar] until the altitude of the solar degree that day. ⟨2⟩ Mark this almucantar and move the rete in the direction of the daily motion, i.e., from the eastern horizon to the western horizon [rightwards]. ⟨3⟩ If you are in the first quarter of the year, which is from March 10th to June [12th],[1] move the rete so that three signs—Aries, Taurus, and Gemini—cross the meridian line. ⟨4⟩ The degree ⟨of any⟩ of these three signs that falls on the almucantar placed on the meridian line is the degree of the sun that day. ⟨5⟩ Identify its ⟨zodiac⟩ sign which is the ⟨zodiac⟩ sign in which the sun is located.

⟨IX.4 Relevance of the knowledge of the right quarter of the year to localizing the sun⟩

⟨1⟩ We ⟨truly⟩ need to know the quarter of the year, because the altitude of the sun above the horizon at midday is the same twice a year, except for the points of ⟨the beginnings of⟩ Cancer and Capricorn, the former being its maximum altitude and the latter its minimum one. ⟨2⟩ According to this (אם כן), the almucantar that the first degree of Taurus ⟨in the rete⟩ intersects, is ⟨also⟩ intersected by the 30th degree of Leo ⟨in the rete⟩ for the distance of each of these two degrees from the equinoctial points is the same.[2]

⟨IX.5 What to do when the instrument does not have an almucantar for the altitude of the sun⟩[3]

⟨1⟩ If the instrument does not have an almucantar for ⟨the exact degree of⟩ the altitude of the sun, first find if the instrument is medial, tertial, and so on [i.e., find its caliber]. ⟨2⟩ Let us say that it is quintile and that the altitude of the sun is, for instance, (55b) 33 degrees [*A3*] at midday. ⟨3⟩ The instrument has almucantars for 30 [*A1*] and for 35 [*A2*] degrees. ⟨4⟩ Turn the rete to place, for instance, the degree 22 of Taurus on the almucantar of 30 degrees [*A1*]. ⟨5⟩ Mark on the limb ⟨the position⟩ of the beginning of Capricorn [*M1*] and ⟨repeat the calculation for the almucantar of 35 degrees [*A2*] also marking the result [*M2*]⟩; observe how many ⟨degrees⟩ there are between the two marks [*M2*-*M1*]; ⟨6⟩ let us say that there are 9 degrees ⟨of difference on the limb⟩. ⟨7⟩ You do according to the method of the proportions, if 9 degrees of the surrounding circle [the limb] correspond to 5 degrees ⟨of difference among the two almucantars⟩, 3 degrees [*A3*-*A1*] ⟨of the almucantars⟩ correspond to 3/5 of them [the nine degrees of the limb], which gives approximately 6 [*M3*-*M1*] degrees. ⟨8⟩ Count six degrees from the first mark [*M1*] toward the position [*lit.* side] of the second one [*M2*] and mark there the intermediate mark [*M3*].

[1] "12th" is my correction of "13th," written in the manuscript, because of what is said in Chapter IX.2 ⟨1⟩ and according to Chapter IX.2 ⟨3⟩.
[2] Cf. Chapters II.4, VIII.2, and IX.2 of this treatise.
[3] This is consequently an approximate method. Ibn Ezra refers to this circumstance only in the second version of his astrolabe text, solving the problem by interpolating between two calculations and indicating that the result is only approximate. See MS Paris BnF heb. 1045, ff. 189b–190a (in Appendix 7 of this monograph).

<.3> <1> וכאשר ידעת הרביע השנה מנה מקו האופק הראשון גשרים כשעור גובה[1] מעלות השמש ליום ההוא. <2> וסמן הגשר ההוא והניע הרשת לצד תנועתה הכללית ר<וצה> ל<ומר> מאופק[2] המזרח אל אופק[3] המערב. <3> ואם אתה ברביע הראשון מהשנה שהוא מי' למרטי עד י"ג[4] לייאוניו הניע הרשת שיעברו ג' מזלות טלה שור תאומים על קו חצי היום. <4> ואי זו מעלה מאחד מאלו הג' מזלות שתמשש הגשר המסומן על קו חצי היום היא מעלת השמש ליום; <5> וראה איזה מזל היא והוא המזל שהשמש בו.

<.4> <1> ואמנם הוצרכנו לדעת הרביע מהשנה מפני שגובה השמש ישתוה בשנה פעמים על האופק בעת חצי היום זולתי בנקודות סרטן וגדי שבאחת בתכלית גובהו והשנית בתכלית שפלותו. <2> ואם כן הגשר שתמשש מעלה הא' משור תמשש מעלה ל' מאריה כי מרחק כל אחד מאלו המעלות מנקודות השווי שוה.

<.5> <1> ואם לא היה בכלי גשר בדמיון גובה השמש דע תחלה אם הכלי חצי או שליש וזולתו. <2> ויהיה ד<רך> מ<של> חמישיי ויהיה גובה השמש ד<רך> מ<של> (55b) בחצי היום ל"ג מעלות. <3> הנה יש בכלי גשר ל' מעלות ול"ה מעלות. <4> ותסבב הרשת ותמשש גשר ל' מעלות מעלת כ"ב משור ד<רך> מ<של>. <5> וסמן עם גדי בתא <...>[5] וראה כמה בין שתי הסמנין, <6> ויהיה ע<ל> ד<רך> מ<זל> ט' מעלות. <7> ותעשה דרך הערכין, אם בין ה' מעלות יהיו ט' מהמקיף, ג' מעלות יהיו ג' חמישיותיהם ויגיעו[6] לו' מעלות בקירוב. <8> מנה מהסימן הראשון לצד השני ששה מעלות וסמן שם סימן אמצעי

[1] Hand seven marked this word with two dots and the following with one to indicate an exchange in their order, so that one reads מעלות גובה rather than גובה מעלות.
[2] Hand seven marked this word with two dots, it is not an indication of mistake.
[3] Hand seven marked this word with two dots, it is not an indication of mistake.
[4] It should be י"ב as in IX.2 ⟨1⟩ and according to IX.2 ⟨3⟩.
[5] There is a sentence missing here necessary to complete the meaning. I have introduced it in my translation between ⟨ ⟩.
[6] ו written in superscript.

⟨9⟩ Place the beginning of Capricorn on the intermediate mark [*M3*] and check which degree of the zodiac is on the meridian. ⟨10⟩ It is approximately the degree of the sun [*A3*].[1]

X CHAPTER: TO KNOW THE ALTITUDE OF ANY ⟨FIXED⟩ STAR IN THE MIDHEAVEN, ⟨THAT IS⟩ WHEN IT IS ON THE MERIDIAN

⟨1⟩ Place the pointer of the ⟨fixed⟩ star that you know is ⟨engraved⟩ on the rete on the meridian line and pay attention to what almucantar falls on it [i.e., on the position of the star]. ⟨2⟩ ⟨This⟩ is the highest altitude the star reaches in your location.[2] ⟨3⟩ If the pointer of the star falls between two almucantars, mark on the limb ⟨the position⟩ of the beginning of Capricorn as we mentioned in Chapter Seven regarding the altitude of the sun ⟨and so on⟩,[3] it is enough with what we mentioned there.

XI CHAPTER: TO KNOW THE ALTITUDE OF THE SUN USING THE KNOWLEDGE OF THE HOUR AND THE POSITION OF THE SUN[4]

⟨1⟩ Place the degree that is the diametrical opposite of the sun on the hour division in which it [the sun] is. ⟨2⟩ Observe on which almucantar the degree of the sun has fallen. ⟨3⟩ Consider the number written on it:[5] it is the altitude of the sun at that moment.[6]

XII (56a) **CHAPTER: TO KNOW THE ASCENSION OF THE ZODIAC ON THE RIGHT AND ON THE OBLIQUE HORIZONS**

⟨XII.1 The ascension of any zodiac sign in the *sphaera recta*⟩

⟨1⟩ If you want to know the ascension of any of the zodiac signs on the right horizon [the *sphaera recta*], place the beginning of the sign on the eastern side of the right horizon line that extends from east to west. ⟨2⟩ Mark on the limb ⟨the position⟩ of the beginning of Capricorn and move the rete in the direction of the daily motion [i.e., rightwards], until this complete sign rises on the ⟨east⟩ line ⟨of the right horizon⟩. ⟨3⟩ Mark on the limb ⟨the position of the beginning of Capricorn⟩. ⟨4⟩ The degrees between the two marks are the degrees of the ascension of this sign on the right horizon [*sphaera recta*].[7]

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[1] This calculating method is widespread in the treatise. See, for example, III.4 ⟨2⟩, IV.7 ⟨8⟩, VII.3 ⟨7⟩–⟨8⟩, XII.3 ⟨6⟩, XXIV ⟨4⟩ and ⟨7⟩, XXVIII.1 ⟨4⟩, ⟨10⟩, ⟨12⟩–⟨13⟩, and ⟨16⟩, XXVIII.2 ⟨4⟩–⟨5⟩, XXVIII.4 ⟨3⟩–⟨5⟩, ⟨7⟩, and ⟨9⟩–⟨11⟩, XXVIII.4a ⟨2⟩, XXVIII.5 ⟨5⟩, XXVIII.5a ⟨5⟩–⟨6⟩, XXVIII.6 ⟨3⟩–⟨4⟩, 6, XXVIII.6a ⟨4⟩–⟨5⟩, and XXVIII.6b ⟨5⟩ and ⟨7⟩–⟨17⟩.

[2] This calculation appears only in Ibn Ezra's second version of his astrolabe text (see MS Paris BnF heb.1045, f. 192b) but there is no mention of what to do with this calculation if the position falls between two almucantars on an astrolabe that is not complete (Chapter X ⟨3⟩ in Moses); of course the solution is interpolating between two calculations, one with the lower almucantar and the other with the higher.

[3] See Chapter VII.3–4, which deal with finding a solution by the interpolation between two calculations, namely, what to do when the instrument is not complete and the degree of the sun falls between two almucantars.

[4] This calculation is a little odd, for the degree of the sun must be known if one wants to know its diametrical opposite. Knowing the degree of the sun one requires finding the time using the altitude of the sun, so this chapter seems to be redundant.

[5] If the latitude plate displays numbered almucantars.

[6] This calculation is just the inverse of telling the time using the altitude of the sun and placing it on the rete according to its almucantar, see Chapter IV.2–IV.3 ⟨1⟩–⟨6⟩.

[7] This calculation is found in Ibn Ezra's three Hebrew treatises on the uses of astrolabes; see MSS Paris BnF heb. 1053, f. 12a (first version), BnF heb. 1045, f. 191b (second version), and Günzburg 937, f. 7b (third version).

<9> ושים ראש גדי על הסימן האמצעי והסתכל אי זו מעלה מהמזלות היא עם קו חצי היום; <10> והיא מעלת השמש בקירוב.

<X> **שער**[1] **לדעת** גובה הככב בחצי השמים בהיותו בקו חצי היום.

<1> שים שן הככב הידוע שהוא ברשת על קו חצי היום ועיין מה שנפל עליו מהגשרים, <2> הנה הוא ביותר גבוה ממה שיפול הככב בארצך. <3> ואם נפל שן הככב בין שני גשרים תסמן בתא עם ראש גדי כמו שהזכרנו[2] בשער ז' במעלת השמש ודי בזכרנו שמה.

<XI> **שער**[3] **לדעת** גובה השמש מפני ידיעת השעה ומקום השמש.

<1> שים מעלה הנכחית למעלת השמש על החלק מהשעה שהוא בה. <2> וראה מעלת השמש על אי זה מהגשרים נפלה <3> וראה המספר הכתוב עליו והוא גובה השמש בעת ההיא.

<XII> (56a) **שער**[4] **לדעת** עליית המזלות באופק הישר והנוטה.

<.1> <1> אם רצית לדעת עליית מזל מהמזלות באופק הישר שים ראש המזל בצד המזרחי מקו האופק הישר ההולך ממזרח למערב. <2> וסמן עם ראש גדי בתא והניע הרשת לצד התנועה הכללית עד עלות[5] כלות המזל ההוא על הקו <3> וסמן בתא. <4> והמעלות שבין שני הסימנין הם שעור עליית המזל ההוא באופק הישר.

[1] Marginal note, hand one: י'.
[2] Crossed out.
[3] Marginal note, hand one: י"א.
[4] Marginal note, hand one: י"ב.
[5] Hand seven marked this word with two dots and the following with one to indicate an exchange in their order, so that one reads כלות עלות rather than עלות כלות.

⟨XII.2 The ascension of any zodiac sign in any oblique horizon⟩

⟨1⟩ If you want to know the ascension ⟨of any sign of the zodiac⟩ in your location, place the beginning of the sign on the first eastern almucantar [*lit.* the line of the eastern horizon] of the ⟨latitude⟩ plate of your location and mark on the limb ⟨the position of the beginning of Capricorn⟩. ⟨2⟩ Move the rete until this sign ⟨completely⟩ rises and mark on the limb ⟨the position of⟩ the beginning of Capricorn. ⟨3⟩ What is between the two marks is the number ⟨of the degrees⟩ of the ascension of the sign on the east line of the horizon in your location.[1] ⟨4⟩ The scholar already explained in ⟨one of⟩ our previous sections [chapters] ⟨the relation of⟩ what is represented on the plane to what is in the ⟨actual⟩ sphere [i.e., the stereographic projection].[2]

⟨XII.3 What to do when there is no plate for one's latitude⟩[3]

⟨1⟩ If you do not have the ⟨latitude⟩ plate of your location [L3], find the ascensions of the zodiac [*A3*] above your location in the following way. ⟨2⟩ First find the ascension of a sign [*A1*] on a horizon [i.e., latitude plate] whose latitude is lower [*L1*] than the latitude of your location. ⟨3⟩ Also find the ascension of this sign [*A2*] on a horizon [i.e., latitude plate] whose latitude is higher [*L2*] than the latitude of ⟨your⟩ location. ⟨4⟩ Find the difference between them and call it the first preservation [*A2-A1*]. ⟨5⟩ Afterwards, find how many degrees there are between the latitude of your location and the location whose latitude is less [*L3-L1*]. ⟨6⟩ Multiply the first preservation by the ratio of ⟨the differences of⟩ the latitude⟨s⟩ [(*L3-L1*)/(*L2-L1*)]; ⟨7⟩ this is called the second preservation.[4]

⟨8⟩ If the zodiac sign you want is between the beginning of Capricorn and the end of Gemini, which are the signs of short ascension—the ascension of any ⟨zodiac sign⟩ going northward gets short⟨er⟩—(56b) subtract the second preservation from ⟨the ascension of the zodiac sign on⟩ the plate whose latitude is lesser than ⟨the latitude of⟩ your location. ⟨9⟩ If it [the zodiac sign that you want] is one of the signs between the beginning of Cancer and the end of Sagittarius, whose ascensions are long—any ⟨zodiac sign⟩ going down northward increases its ascension—add the second preservation to the ascension of the sign ⟨in the location⟩ whose latitude is lesser than ⟨the latitude of⟩ your location. ⟨10⟩ The result is the ascension of that sign in your location.

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[1] The same calculation appears in Ibn Ezra's three Hebrew treatises; see MSS Paris BnF heb. 1053, f. 12a (first version), BnF heb. 1045, f. 191b (second version), and Günzburg 937, f. 7b (third version).

[2] Moses' explanation implies that the great circles become straight lines on the stereographic projection. See Chapter II.7, where Moses refers to Theodosius of Bithynia's explanation on the great circles of the sphere. As Theodosius did not treat stereographic projection, I have not been able to identify the scholar referred to in this sentence. See also Chapter III.4.

[3] This circumstance is not considered in Ibn Ezra's treatises, but as in similar situations, the solution is found by interpolating between two calculations.

[4] Ibn Ezra was the only writer using the expressions "first preservation" and "second preservation" in the explanation of the uses of astrolabes. Moses' terminology makes apparent the influence of Abraham Ibn Ezra's text on the astrolabe in this section. Furthermore, one can confirm that Moses ben Abraham used either the first or the second versions, where these two terms are used in the same context. For Ibn Ezra's versions of his astrolabe text and their differences, see Rodríguez-Arribas 2014, 237–249.

<2.> <1> ואם תרצה לדעת עלייתו בארצך שים תחלה המזל בלוח ארצך על קו האופק המזרחי וסמן בתא. <2> והניע הרשת עד עלות המזל ההוא וסמן בתא עם ראש גדי. <3> ומה שבין שני הסימנין הוא שעור עליית המזל בארצך על קו האופק המזרחי. <4> וכבר התבאר בספרינו הקודם לזה החכם זה בשטח אל מה שהוא בכדור.

<3.> <1> ואם לא היה לך לוח ארצך תדע מעלות המזלות על ארצך כן. <2> דע תחלה עליית מזל מה באופק שהוא פחות מרחבו מרוחב ארצך. <3> גם דע עליית המזל ההוא באופק שמרחבו יותר מרוחב ארץ. <4> וראה כמה ביניהם מההפרש ויקרא השמור הראשון. <5> אחר ראה כמה מעלות הוא מרחב ארצך מן הארץ הפחות מרחב ממנה. <6> וקח כדמות הערך ההוא אל כל המרחב מן השמור הראשון, <7> ויקרא שמור שני.
<8> ואם המזל שתרצה הוא מראש גדי עד סוף תאומים שהם מזלות קצרי המצעדים וכל מה שילכו לצד צפון יקצר מצעדם, (56b) גרע השמור השני מהלוח הפחות מרחב [מ]ארצך[1]. <9> ואם הוא מהמזלות שמראש סרטן עד סוף קשת אשר הם ארוכי [ה]מצעדים[2] וכל מה שיעמיקו בצפון יגדל מצעדם, הוסף השמור השני על עליית המזל ברוחב הפחות מארצך. <10> והעולה הוא עליית המזל ההוא בארצך.

[1] Interlineal addition, hand two.
[2] Interlineal addition, hand two.

XIII CHAPTER: TO KNOW THE POSITIONS OF THE PLANETS[1]

⟨XIII.1 Method one: When any of the superior planets or the moon is rising⟩[2]

⟨1⟩ You can know the position⟨s⟩ of Saturn, Jupiter, Mars, and the moon by three methods. ⟨2⟩ First ⟨method⟩, when the planet is rising. ⟨3⟩ ⟨In this case⟩ take the degrees of the altitude of one of the ⟨fixed⟩ stars ⟨at that moment⟩ and find the rising degree ⟨according to what has been explained before⟩. ⟨4⟩ The planet is there.

⟨XIII.2 Method two: When any of the superior planets is setting⟩

⟨1⟩ Second ⟨method⟩, when the planet is setting. ⟨2⟩ ⟨In this case⟩ take the degrees of the altitude of one of the [fixed stars].[3] ⟨3⟩ In the same way you know the ⟨position of the planet when it is⟩ rising ⟨by method one⟩, you ⟨can also⟩ know the ⟨position of the planet when it is⟩ setting ⟨by the same method⟩.

⟨XIII.3 Method three: When any of the superior planets is on the meridian⟩

⟨1⟩ Third ⟨method⟩, when the planet is on the meridian. ⟨2⟩ Observe what is the altitude of the planet. ⟨3⟩ After knowing the quadrant of the zodiac in which the position of the planet is situated, move the rete ⟨to the position of the altitude of the planet⟩. ⟨4⟩ The degree that falls on the almucantar that corresponds to the altitude of the planet ⟨and on the meridian⟩ is the position of the planet, as was done before for the sun.

⟨XIII.3a Conditions under which method three is the most accurate⟩

⟨1⟩ This method is more correct than the previous ones, ⟨because with them⟩ you cannot estimate the moment of the rising or the setting ⟨of the planet⟩ with accuracy. ⟨2⟩ In spite of this, all the methods are approximate when the planet has ecliptic latitude.[4]

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[1] The Hebrew word *mešartim* ("planets") is distinctive of Abraham Ibn Ezra, who introduced it in the 12th century to denote the planets in his astrological, astronomical, and exegetical writings (although it was already used in the *Baraita di-Shmuel*). For Ibn Ezra's technical terminology in his astrolabe treatises, see Rodríguez-Arribas 2016, 93–94 and 96–105. *Mešartim* is used only in the second version of Ibn Ezra's text on the astrolabe (see MS Paris BnF heb. 1045, ff. 188b, 189b, 190a, 192b, et cetera), which confirms that Moses might have used this second version rather than the first or the third.

[2] These three methods to calculate the position of the planets and the moon using an astrolabe are described in several manuscripts; see Abraham Ibn Ezra's three versions of his astrolabe text and the similar methods described to find the position of the moon (by method one and two) and the planets (by method three) in the anonymous Hebrew version of the astrolabe texts associated to Hermann of Reichenau, MS Oxford Bodleian Libraries Opp. 579, f. 61a (Appendix 2 of this monograph). A consideration of these methods makes apparent that Moses ben Abraham is following Abraham Ibn Ezra's description of the three methods (XIII.1–3 and XIII.4–4a) according to the second version of his astrolabe text. Moses quotes the first and the second methods literally and the third more freely introducing some differences in the wording and skipping technical information that Ibn Ezra provides. For instance, Moses omits the instructions to improve the calculation of the positions of the superior planets when they have ecliptical latitude and are rising (adding to or subtracting from 2/3 of the corresponding latitude of the planet when it is southern or northern, respectively) and does not mention the specific values of the elongations of Venus and Mercury, about 47º and 29º, respectively.

[3] "Fixed stars" is my correction of "superior planets," written in the manuscript.

[4] He means that in this circumstance all three methods are approximate.

<XIII> שער[1] **לדעת** מקומות המשרתים.

<.1> <1> הנה מקום שבתאי צדק ומאדים והלבנה תוכל לדעת מקומם מג' פנים. <2> האחד[2] בזרוח המשרת: <3> תקח מעלות גבהות אחד מהככבים והוצא המעלה הצומחת, <4> ושם הככב.

<.2> <1> והדרך השני בשקוע הככב <2> שתקח מעלות גבהות אחד העליונים, <3> ובדעתך הזורחת תדע השוקעת.

<.3> <1> והדרך השלישית בהיותו בחצי השמים, <2> הסתכל כמה גבהות הככב. <3> ואחר שתדע מקום המשרת באי זה רביעית מהמזלות הוא והניע הרשת, <4> והמעלה שתמשש הגשר שבדמיון גובה הככב שם מקום המשרת בדרך שקדם בשמש.

<.3א> <1> וזו הדרך נכונה מהדרכי<ם> הקודמי<ם> להיות שלא תוכל לשער עת הזריחה[3] או השקיעה שלו בדקדוק, <2> א<ף> ע<ל> פ<י> שכל הדרכי<ם> קרובי<ם> בהיות לככב מרחב מאופן המזלות.

[1] Marginal note, hand one: י"ג.
[2] ד written in superscript.
[3] ה written in superscript.

⟨3⟩ This [i.e., the optimal conditions to get most accuracy] happens when the planet ⟨is in the ecliptic but⟩ neither rises nor sets with its ⟨zodiac⟩ degree, and culminates neither with it nor with another ⟨zodiac⟩ degree in any of the three positions, except with the degrees of the solstices as we are going to explain more ⟨below⟩.

⟨XIII.4 What happens when any of the inferior planets are in the ecliptic⟩

⟨1⟩ However, when the planet does not have latitude, which happens when it is either at the Head or at the Tail [i.e., its nodes],[1] you can know the position of Venus and Mercury when they are rising (57a) or setting. ⟨2⟩ Yet, it is not possible to know them by the method of the meridian [the third method], because Mercury does not depart from the sun except by only half the diameter of its deferent circle. ⟨3⟩ The same for Venus.[2]

⟨XIII.4a Exception: Venus at noon in the seventh clima⟩

⟨1⟩ If ⟨the location⟩ is in the seventh clima,[3] which Ptolemy calls Small Britannia [i.e., Ireland] and is ⟨placed⟩ after In⟨g⟩laterra [i.e., England] in the west,[4] and the sun is in Capricorn and Venus around the end of Scorpio, you can know its position at noon, for the extremity of the circle of the beginning of Capricorn on that horizon is very close ⟨to the meridian at noon⟩.[5] ⟨2⟩ For this reason, it can happen that the sun sets and Venus is on the meridian, or that Venus is on the meridian and the sun has not risen yet.

[1] Like the moon, the planets also cross the ecliptic in two places: the south node, when the planet crosses the ecliptic going southward, and the north node, when the planet crosses the ecliptic going northward.

[2] In the geocentric medieval system of the universe, the sun turns around the centre of the motionless Earth on an eccentric path; the remaining planets move around the stationary Earth on an epicycle with its centre on a circumference (the deferent), the centre of which is a stationary point separated from the centre of the Earth. The angular velocity of the planet is uniform not with respect to the Earth or the centre of the deferent but with respect to the equant, a point placed inside the deferent but not necessarily coinciding with its centre. This was not understood as a physical system (with a few exceptions), but rather as a model that worked rather well in predicting quantitative positions most of the times although it underwent several criticisms and modifications before the time of Copernicus. For an overview of the system, see for instance Grant 1996, 104–112; for some of the criticisms of the model, see Goldstein 1985, 2–9.

[3] Another Hebrew term that is characteristic of Abraham Ibn Ezra, who used it to denote any of the climas; see Sela 2019, 358–359, which repeats in a concise form his previous study in Sela 2003, 107–112.

[4] *Britannia Magna* and *Britannia Parva* (or in Greek *Megalē Britannia* and *Mikrē Britannia*) respectively in classical sources, see for instance Ptolemy, *Geography*, II, 2.

[5] In Moses ben Abraham’s text, the fact is that in this situation the latitude of the location is very close to the meridian altitude of the sun at the beginning of Capricorn. As the elongation of Venus is known, its position can be calculated. See the same remark in Ibn Ezra’s second version of his astrolabe text, MS Paris BnF heb. 1045, f. 193a.

<3> וזה להיות שהככב לא יצמח עם מעלתו ולא ישקע עמה ולא ימצע עמה השמי<ם> ולא עם מעלה אחרת בג' המקומות רק עם מעלות מתחלפות כאשר[1] נבאר עוד.

<4.> <1> אבל כשאין לככב מרחב וזה בהיותו באחת[2] התנין או הזנב ותוכל לדעת מקום נגה וככב חמה בזורחם (57a) גם בשקעם. <2> רק בדרך חצי השמים לא יתכן לדעתם בעבור כי לא יתרחק ככב חמה מהשמש רק כמו שעור חצי קטר גלגל הקפתו לבד, <3> וככה בנגה.

<4א.> <1> ואם היתה בגבול הז' שיקראה בטלמיוס ברטנייא הקטנה והיא אחרי אינלאטירה בפאת מערב והשמש במזל גדי ונגה בעקרב אצל סופו, תוכל לדעת מקומו בחצי השמים להיות שמה שיכלה מעגול ראש גדי באופק ההוא הוא מעט מאד. <2> ולכן יתכן שישקע השמש ויהיה נגה בחצי השמים או שיהיה נגה בחצי השמים ועדיין לא יזרח השמש.

1 ר written in superscript.
2 It should be בראש.

XIV CHAPTER: TO KNOW THE HOUR OF THE RISING OF ANY ZODIAC DEGREE YOU WANT OR ANY OF THE ⟨FIXED⟩ STARS ENGRAVED ON THE RETE ⟨WHOSE RISING⟩ IN THE EASTERN HORIZON OR WHOSE SETTING YOU WANT ⟨TO KNOW⟩

⟨XIV.1 The rising and the setting of any degree of the zodiac on the local horizon⟩[1]

⟨1⟩ When you want to know this, place the degree or the pointer of the star you want on the line of the eastern horizon. ⟨2⟩ If the degree of the sun is above the earth, the moment of the rising of this degree is in the daytime. ⟨3⟩ Observe in which hour of the ⟨nocturnal⟩ arc the diametrical opposite of the sun has fallen, it is the hour of the rising of this degree. ⟨4⟩ If the degree of the sun is below the horizon, the rising of this degree is in the nighttime at the hour on which the degree of the sun has fallen. ⟨5⟩ The same happens if you place this degree on the western horizon.

⟨XIV.2 The culmination of any degree of the zodiac on the local horizon⟩

⟨1⟩ If you want to know the moment at which it [the degree of the zodiac] culminates, place the degree on the line of the ⟨upper⟩ meridian. ⟨2⟩ Observe where the position of the solar degree has fallen and do as ⟨you did⟩ before.[2]

XV (57b) CHAPTER: TO KNOW THE DECLINATION OF ANY DEGREE OF THE ZODIAC WITH RESPECT TO THE EQUATOR

⟨XV.1 The declination of any degree of the zodiac⟩

⟨1⟩ When you want this, place the degree whose declination you want to know on the meridian line, find on which ⟨degree⟩ the altitude ⟨of the degree⟩ has fallen, and keep it. ⟨2⟩ Also find the altitude of the equinox.[3] ⟨3⟩ The difference between ⟨the degrees of⟩ the two altitudes is the declination of that degree.

⟨XV.2 The declination of any fixed star⟩

⟨1⟩ You know in the same way the declination with respect to the equator of any of the ⟨fixed⟩ stars ⟨engraved⟩ on the rete. ⟨2⟩ You place the pointer of the star on the meridian line and this is the ⟨meridian⟩ altitude of the star. ⟨3⟩ The degrees ⟨of the difference⟩ between its altitude and the altitude of the beginning of Aries is its distance ⟨from the equator and hence the declination of the star⟩.[4]

[1] The specific calculation appears only in the first version of Ibn Ezra’s Hebrew treatise on the astrolabe (see MS Paris BnF heb. 1053, f. 11a–11b) but the calculation to find the zodiac degree with which a fixed star rises or sets is in the three Hebrew versions; see MSS Paris BnF heb. 1053, f, 21a (first version), Paris BnF heb. 1045, f. 192b (second version), and Günzburg 937, f. 8b (third version).
[2] The culmination of zodiac degrees is not found in Ibn Ezra’s Hebrew treatises.
[3] According to what has been explained in Chapter VIII.8a.
[4] These calculations (XV.1–2) appear only in Ibn Ezra’s Hebrew first version of his astrolabe text; see MS Paris BnF heb. 1053, f. 11a.

<XIV> **שער**[1] **לדעת** שעת עליית איזו מעלה שתרצה מן המזלות או <אי>זה ככב שתרצה מן הככבים המונחים ברשת על קו האופק המזרחי או שקיעתו.
<.1> <1> כשתרצה לדעת זה שים המעלה או שן הככב שרצית על קו האופק המזרחי. <2> ואם מעלת השמש היתה על הארץ הנה עת עליית המעלה ההיא הוא ביום. <3> ראה מעלה הנכחית לשמש על אי זו שעה מקשת נפלה והוא שעת עליית המעלה ההיא. <4> ואם מעלת השמש תחת האופק הנה עליית המעלה ההיא תהיה בלילה כפי שעור מהשעות שנפלה עליהם מעלת השמש. <5> וככה אם תשים המעלה ההיא על האופק המערבי.

<.2> <1> **ואם** תרצה לדעת העת שימצעו בה השמים שים המעלה על קו חצי היום, <2> וראה מעלת מקום השמש אנא נפלה ותעשה בדרך שקדם.

<XIV> (57b) **שער**[2] **לדעת** [נטיית][3] אי זו מעלה מעגולת המזלו<ת> מעל המשוה.
<.1> <1> כשתרצה זה שים המעלה אשר תרצה ידיעת נטייתה על קו חצי היום ודע על כמה תפול מן הגובה ושמרהו. <2> עוד דע על כמה מן הגובה היא עגולת משוה היום, <3> ומה שבין שני הגובהים הוא שעור נטיית המעלה ההיא.

<.2> <1> וכזה תדע נטיית אי זה ככב מהככבים שברשת מהמשוה. <2> כשתשים שן הככב על קו חצי היום והוא שעור גובה הככב. <3> והמעלות שבין גובהו ובין גובה ראש טלה הוא שעור מרחבו.

[1] Marginal note, hand one: י"ד.
[2] Marginal note, hand one: ט"ו.
[3] Interlineal addition, hand two.

⟨XV.2a Demonstration of this calculation⟩

⟨1⟩ The reason is apparent to whomever understands the foundation of the craft. ⟨2⟩ We already explained in ⟨one of⟩ our previous sections [chapters] that the almucantars are placed so that they intersect two circles parallel to the equator.[1] ⟨3⟩ The distance between the circles of these almucantars is one degree when the instrument is complete. ⟨4⟩ We already measured the altitude ⟨of the corresponding fixed star⟩ using the almucantars.[2] ⟨5⟩ The degrees between the two altitudes ⟨the altitude of the star and the altitude of the beginning of Aries⟩ are the distance (המרחב) ⟨of the star from the equator and so these are the degrees of its declination⟩.

⟨6⟩ Know that the southern signs always subtract their altitude from the altitude of the beginning of Aries, which is their declination. ⟨7⟩ However, the northern ⟨signs⟩ add their altitude to the ⟨altitude of the⟩ beginning of Aries, which is their declination. ⟨8⟩ This happens in locations whose latitude (שמרחבם) is higher than ⟨their⟩ declination; be aware of this. ⟨9⟩ Know that the accurate declination is easily found with the tables, but there is no accuracy in this using the astrolabe.[3]

XVI CHAPTER: TO KNOW WITH WHICH ZODIAC DEGREE ANY OF THE ⟨FIXED⟩ STARS—NOT ON THE ECLIPTIC—RISES, CULMINATES, AND SETS

⟨1⟩ When we want to know this, (58a) we place the pointer of the star on the line of the eastern horizon and observe which degree of the zodiac is there. ⟨2⟩ This is the zodiac degree with which that star rises above that horizon. ⟨3⟩ If you want to know with which degree it sets, place the pointer of the star on the western horizon. ⟨4⟩ It is the degree with which the star sets. ⟨5⟩ If you want to know the degree with which it culminates, place the pointer of the star on the meridian line. ⟨6⟩ The zodiac degree on the meridian line on the side of the upper midheaven is the degree with which the star culminates. ⟨7⟩ All this is clear as regards the projection onto the plane, which represents the ⟨actual⟩ sphere that is not visible (בעינו), and whose understanding is not in your depiction.[4]

XVII CHAPTER: TO KNOW THE DIURNAL AND THE NOCTURNAL ARCS OF THE STAR ⟨OR PLANET⟩

⟨1⟩ Know that the diurnal arc of the star is the time of its [i.e., the star's] standing above the earth, while its nocturnal arc is ⟨the time of⟩ its standing below [the earth]. ⟨2⟩ When you want the diurnal arc, place on the line of the eastern horizon the degree ⟨of the zodiac in the rete⟩ with which the star rises. ⟨3⟩ Mark on the limb ⟨the position⟩ of the beginning of Capricorn and turn the rete in the direction of its ⟨natural⟩ motion [rightwards][5] until the degree with which the star sets is on the line of the eastern horizon.

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[1] Refence to Chapters III.4 and IV.4a ⟨1⟩–⟨4⟩.

[2] See Chapter III.2 (calculation of the altitude of any fixed star).

[3] More concern by Moses ben Abraham with the accuracy of the instrument and the approximative character of some calculations; see also VII.4 and XIII.3a.

[4] Part of this calculation (rising and setting) is found in the three Hebrew versions of Ibn Ezra's astrolabe text; Paris BnF heb. 1053, f. 21a (first version), 1045, f. 192b (second version), and Günzburg 937, f. 8b (third version).

[5] Which is the direction of the daily motion for the observer.

<2א.> <1> **והסבה** מבוארת למבין שרש המלאכה <2> שכבר בארנו בספרינו הקודם לזה שהגשרים הונחו ממששים שתי עגולות נכוחיות למשוה. <3> רוחק כל עגולה מעגולה מאלו הגשרים מעלה אחת אם הכלי שלם. <4> וכבר היה הגובה נלקח עם הגשרים. <5> הנה מה שבין גובה לגובה הם שעור מעלות המרחב.
<6> ודע כי לעולם המזלות הדרומיות יחסר גובהם מגובה ראש טלה כשעור נטייתם. <7> והמזלות הצפוניות תרבה גובהם על ראש טלה בשעור נטייתם. <8> וזה במקומות שמרחבם גדול משעור הנטייה ודע זה. <9> ודע כי הנטייה המדוקדקת[1] תוצא בקלות עם הלוחות ובכלי אי אפש<ר> שידוקדק בו זה.

<XVI> **שער**[2] **לדעת** אי זו מעלה מהמזלות יעלו וימצעו השמים וישקעו כל הככבים שאינם באפודת המזלות.

<1> כשנרצה לדעת זה (58a) נשים שן הככב על קו האופק המזרחי ונראה אי זו מעלה[3] מהמזלות היא על האופק, <2> ועם אותה המעלה מהמזלו<ת> יעלה הככב ההוא על האופק ההוא. <3> ואם תרצה לדעת עם אי זו מעלה ישקע שים שן הככב על האופק המערבי, <4> היא המעלה שישקע עמה הככב. <5> ואם תרצה לדעת המעלה שימצעו עמה השמים שים שן הככב עם [קו][4] חצי היום, <6> והמעלה מהמזלות שיהיה עם קו חצי היום לצד נקודת חצי השמים היא המעלה שימצעו עמה הככב השמים. <7> וכל אלו הדברים מבוארים להיות מצב השטח כמצב הכדור בעינו והבינהו אינה בציורך.

<XVII> **שער**[5] **לדעת** קשת יום הככב וקשת לילו.

<1> דע כי קשת יום הככב הוא זמן עמידתו על הארץ וקשת הלילה הוא עמידתו תחתיה. <2> כשתרצה קשת היום שים המעלה שיצמח עמה הככב על קו האופק המזרחי, <3> וסמן עם ראש גדי בתא וסבב הרשת דרך תנועתה עד בוא המעלה שישקע עמה הככב על קו האופק המזרחי.

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[1] ת written in superscript.
[2] Marginal note, hand one: י"ו.
[3] ה written in superscript.
[4] Interlineal addition, possibly by hand two.
[5] Marginal note, hand one: י"ז.

⟨4⟩ The degrees between the two marks is the diurnal arc of the star. ⟨5⟩ If you subtract this from 360, the remainder is the nocturnal arc of the star.[1]

XVIII CHAPTER: ON ⟨THE IMPOSSIBILITY OF⟩ KNOWING THE POSITION [I.E., THE LONGITUDE] OF ANY FIXED STAR IN THE ZODIAC ⟨WITH AN ASTROLABE⟩

⟨1⟩ We already said in the first part ⟨of the treatise⟩ that,[2] according to the true method of engraving (חקיקת) the stars on the rete,[3] the position of the ⟨fixed⟩ star cannot be found, neither with the method of the sage rabbi Abraham Ibn Ezra[4] nor with the method of the great sage (58b) Rabbi Mordechai ⟨Comtino⟩, may his rest be in the Garden of Eden.[5] ⟨2⟩ We are left with the task of studying how to find the position [the longitude] of the star. ⟨3⟩ I say that, in my view, there is no method to find the position [the longitude] of any fixed star with the astrolabe. ⟨4⟩ Moreover I did not find in Ptolemy's explanation of the instrument any method to find this.[6]

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[1] This calculation appears in the three versions of Ibn Ezra's astrolabe text; see MSS Paris BnF heb. 1053, ff. 21a–21b (first version), BnF heb. 1045, f. 192b (second version), and Günzburg 937, f. 8b (third version).

[2] There is no mention of this topic in Chapter I of Moses' treatise on the astrolabe. This allusion implies that Moses wrote about the construction of the astrolabe, which is the context for any explanation of methods for placing star pointers in the rete. Should we assume that Moses wrote a treatise explaining the construction of astrolabes and that this text has not survived? I have not been able to answer this question.

[3] What is this method that is being referred to here? Is Moses referring to another part of this codex or to a previous work that remains unnamed and unidentified for his readers? This unidentified text must have been about the construction of the astrolabe, given that the construction of the pointers of the stars is described in it.

[4] For Abraham Ibn Ezra's remarks on the longitude of stars and how to update them using tables, see Appendix 3 of this monograph (first and second versions). It is not clear which version Moses ben Abraham is using.

[5] "May his rest be in the Garden of Eden" is only used after the name of a deceased person. The use of this expression to refer to Comtino means that Comtino (died in 1482) was already dead when Moses ibn Abraham mentioned him and that perhaps Moses had met him or was addressing readers who had met him. For Comtino's approach to the construction of star pointers on the rete, see his treatise on the northern astrolabe, MS Paris BnF heb. 1095, ff. 135b–138b. It is not clear why Moses is putting side-by-side Ibn Ezra's text, on calculating stellar positions with an astrolabe, and Comtino's text on the construction of the star pointers with no reference at all to their use in calculations with astrolabes. Might Comtino have written a text on the uses of astrolabes that is not extant but was still available in Moses' times? Or perhaps this is a reference to an oral teaching by Comtino?

[6] This might refer to Ptolemy's *Planispherium*; see Sidoli and Berggren 2007, 109 [20.2] (the text) and 136 (explanation): "It follows from this that we can draw the stars in the locations found in the measure with respect to the equator, without drawing all circles, with only a division of the equator and a ruler divided according to the ratios of the circles parallel to the equator. As for the locations found in the measure with respect to the circle through the signs, this is not possible. We must, rather, draw every circle, or most of them, in order to be guided by them regarding the positions in which the stars must be set out." There is a medieval Hebrew version of this text, apparently based on a Latin translation from the Arabic. For the Latin version of Hermann of Carinthia, see Kunitzsch 1993; and for the Hebrew one, see Lorch 1995, 276, n. 11: MS London, British Library Alm. 96 II (1002 in Margoliouth's catalogue) and MS Oxford Bodleian Libraries Opp. Add. 4º 175 (2582 in Neubauer's catalogue). But Moses' reference also might be to a text on the construction of astrolabes attributed to Ptolemy, the one I have referred above as using the construct expression *keli habaṭah* to name this instrument. I have inspected the Oxford MS and there are two works attributed to Ptolemy in it: *Moftei keli ha-habaṭah* (ff. 1a–12b) and *Maʿaseh keli ha-habaṭah ha-niqra asṭurlab ve-hu le-Baṭalmius le-šiveʿah aqlimim* (ff. 13a–19a); they both deal with the construction of an astrolabe.

<4> ומה שבין שני הסימנין הוא קשת יום הככב, <5> ואם תגרע זה מש"ס יהיה הנשאר קשת ליל הככב.

<XVIII> שער[1] לדעת[2] מקום הככב הקיים מאפודת המזלות.

<1> כבר אמרנו בחלק הראשון כי לפי דרך חקיקת הככבים על הרשת האמיתית לא יצא מקום הככב לא עם דרך החכם <רבי> א<ברהם> ב<ן> ע<זרא> ולא עם דרך החכם הגדול (58b) ר<בי> מרדכי נ<וחו> ע<דן>. <2> ונשאר עלינו לחקור איך נדע מקום הככב. <3> ואומר כי הנה אני חושב שאין דרך לדעת מקום הככב הקיים בכלי האצטרולב. <4> ולזה לא מצאתי שבטלמיוס לא נתן דרך בפירושו לכלי להוציא זה

[1] Marginal note, hand one: י"ח.
[2] The title of this chapter is not in bold script.

⟨5⟩ In the explanation of the instrument in 42 chapters by one of the great Muslim sages, in which he explained all the remaining questions, he also did not give us any method to find the position [the longitude] of any fixed star.[1] ⟨6⟩ It seems that there is agreement that we do not have any method to find this using the astrolabe.[2]

XIX CHAPTER: TO KNOW THE LATITUDE OF ANY FIXED STAR WITH RESPECT TO THE ECLIPTIC

⟨XIX.1 The ecliptic latitude of any fixed star⟩

⟨1⟩ When you want this, place the pointer of the star on the meridian line. ⟨2⟩ Observe on which degree this pointer falls, i.e., look the number written on the almucantar on which the pointer is;[3] it is the altitude of the star. ⟨3⟩ Observe on which almucantar degree is the zodiac degree on the meridian. ⟨4⟩ The difference you find between the two degrees is the ecliptic latitude ⟨of the star⟩. ⟨5⟩ If the degrees of the star are more than the zodiac degree, it is northern. ⟨6⟩ If they are less, it is southern.[4]

⟨XIX.2 Refutation of Abraham Ibn Ezra's and Mordeḵai Comtino's methods⟩

⟨1⟩ Know that this way [*lit.* question] of ⟨calculating⟩ the latitude is also according to the method of rabbi Abraham Ibn Ezra, of blessed memory.

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[1] This reference must be to Abū al-Qāsim Aḥmad ibn al-Ṣaffār (d. 1035), who wrote a treatise on the use of astrolabes (extant in three Arabic versions) that was translated into Hebrew at least twice, first by Jacob ben Maḵir ibn Tibbon (1271–1275) and almost three centuries later by Moses ben Baruch Almosnino (1518–1579/80); see Zonta 2011, 34; and Robinson and Melammed 2007,19:712 (both in relation to Ben Maḵir); and Sheynin 2015), 343–350 (this article contains some imprecisions). In relation to Ibn al-Ṣaffār's treatise, see Millás Vallicrosa 1955, 35–49 (study in Spanish) and 47–76 (edition of Ibn al-Ṣaffār's text in Arabic); 1931, 29–48 (Catalan translation of Ibn al-Ṣaffār's text); and Kunitzsch 1989, 48 (chapter X). Here Kunitzsch refers to the 42 chapters of the Arabic version of Ibn al-Ṣaffār edited by Millás Vallicrosa (MS Escorial 964) and the 32 chapters of the unedited longer version (MS London British Library Add. 9600, ff. 262v–280v). According to Kunitzsch there exists another third version of Ibn al-Ṣaffār's text by ʿAbdallāh ibn Muḥammad ibn Saʿd al-Tuǧībī (MS Berlin Staatsbibliothek Ahlwardt 5805, ff. 68v–81r). I heartily thank Taro Mimura for this reference and for providing me with a copy of Kunitzsch's article. There is no reference to the longitude of the stars and its calculation with an astrolabe in Ibn al-Ṣaffār's Arabic version published by Millás Vallicrosa. For Ibn al-Ṣaffār's method of localizing the stars with an astrolabe, see Appendix 4 of this monograph where the methods referred to concern (1) the altitude of any star on the meridian or (2) the recognition of an unknown star engraved on the rete using another star whose position is already known.

[2] He gives up the problem because the only way to know the longitude of the star is with updated tables indicating this coordinate of the stars. Ibn Ezra discusses this situation in the first and second versions of his astrolabe text, where he refers to tables and the method to update them when they are outdated; see Appendix 3 of this monograph.

[3] If the latitude plate displays numbered almucantars, otherwise one has to count and calculate.

[4] For Ibn Ezra's method, which he is following (either in the first or the second versions, Moses has much reduced his source so the identification of the version is not easy; it might be either of them), see Appendix 4 of this monograph (first and second versions). Ibn Ezra's explanation in the two versions is much longer and gives alternative methods (for these calculations) that Moses omits.

<5> גם בפי<רוש> הכלי לחכם גדול מחכמי ישמעאל בו מ"ב שערים פי<רש> כל שאר הענינים ולא נתן לנו דרך לידיעת מקום הככב הקיים. <6> נראים שהסכים בשאין לנו דרך לידיעת זה מכלי האצטרולב.

<XIX> שער[1] לדעת[2] מרחב הככב הקיים מן אפודת המזלו<ת>.

<.1> <1> כשתרצה זה שים שן הככב בקו חצי השמים <2> והסתכל על כמה מעלות הוא השן רצו<ני> שתראה הגשר שהשן עליו מה מספר כתו<ב> עליו, והוא גובה הככב. <3> וראה המעלה מהמזלות שהיא בחצי השמים על כמה מעלות היא בגשרים <4> ואשר תמצא בין שתי המעלות הוא המרחב. <5> ואם מעלות הככב יותר ממעלות המעלה מן המזלות הוא שמאלי, <6> ואם פחות הוא דרומי.

<.2> <1> ודע כי זה הענין במרחב גם כן הנה הוא דרך ר<בי> א<ברהם> ב<ן> ע<זרא> ז<כרונו> ל<ברכה>.

[1] Marginal note, hand one: י"ט.
[2] The title of this chapter is not in bold script.

⟨2⟩ However, according to our method,[1] this is not the ecliptic latitude of the star, because the degree with the star in the midheaven is the degree of the star insofar as the latitude ⟨of the star⟩ is related to the degree on which the almucantar falls. ⟨3⟩ I am astonished that the great sage rabbi Mordeḵai ⟨Comtino⟩, may his rest be in the Garden of Eden, did not clarify how to find the ecliptic latitude of any star except according to his own method [Comtino's].[2] ⟨4⟩ Yet this is not the latitude of the star either. ⟨5⟩ Perhaps he was not interested in getting further in this.[3]

XX (59a) **CHAPTER: TO KNOW THE AZIMUTH OF THE SUN BY DAY AND OF ANY STAR BY NIGHT**

⟨XX.1 The four quadrants of the horizon⟩

⟨1⟩ The meaning of this is that the horizon is divided into four quadrants [*lit.* parts] by the circle ⟨crossing⟩ the zenith and the circle of the meridian, which on the astrolabe is the vertical line. ⟨2⟩ The first quadrant [*lit.* part] is from the angle of the midheaven to the east and is called eastern-southern. ⟨3⟩ The quadrant [*lit.* part] from the angle of the earth to the east is called eastern-northern. ⟨4⟩ The quadrant [*lit.* part] from the angle of the midheaven to the west is called western-southern. ⟨5⟩ And the quadrant [*lit.* part] below ⟨from the angle of the earth to the west⟩ is western-northern.[4]

⟨XX.2 The quadrant of the sun or any visible star or planet by day⟩

⟨1⟩ You want to know in which of these quadrants the star is visible and how many degrees of the horizon there are between the central point of the east and the west [i.e., the true east and west] and the point at which the horizon intersects the circle of altitude crossing the zenith and the star at that moment. ⟨2⟩ Find the altitude of the sun at that moment and place the solar degree among the almucantars according to its altitude. ⟨3⟩ If ⟨the sun⟩ is in the east, ⟨place it⟩ among the eastern almucantars, but if it is in the west, ⟨place it⟩ among the western ones.

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[1] This method remains unexplained in Moses ben Abraham's treatise. It might refer to some oral explanation previously given in a teaching context.

[2] Moses' mention of Comtino's is surprising given that there is no extant text on the uses of astrolabes (and so on the calculation of stellar positions with it) by Comtino, only texts on the construction of two forms of the instrument (northern and southern). The reference might be to a text on the uses that has not survived.

[3] Moses ben Abraham is harshly critical of the two main authors of astrolabe literature in Hebrew who worked in the Sephardic tradition and drew mainly from Arabic sources. Ibn Ezra and Comtino were themselves very critical in their respective approaches to the instrument (we have already quoted Ibn Ezra's remarks), and as regards Comtino, despite being a passionate admirer of Ibn Ezra's works, he criticised Ibn Ezra's texts on the astrolabe and tried to improve them with his own work. See the introduction of his *Treatise on the northern astrolabe* (MS Paris BnF heb. 1095, f. 123a).

[4] Notice again the overlapping of astrological and astronomical terminology (*yeted ha-areṣ* rather than any other expression meaning the lower meridian or the line of the midnight). For the four quadrants in Ibn Ezra's Hebrew astrolabe texts, see MSS Paris BnF heb. 1053, ff. 2b–3a (first version), BnF heb. 1045, f. 188a, and Günzburg 937, f. 4b (third version).

<2> אמנם לפי דרכנו אינו זה מרחב הככב כי המעלה שעם הככב בחצי השמים הנה מעלת הככב עד שישוער המרחב בערך אל המעלה שתפול עליה מהגשרים. <3> ואתמה על החכם הגדול ר<בי> מרדכי נ<וחו> ע<דן> איך לא בירר איך נדע מרחב הככב כי לפי דרכו <4> גם כן לא יהיה זה מרחב הככב. <5> ואולי לקירוב הענין[1] לא חשש בו.

<XX> (59a) **שער[2] לדעת** סמות השמש ביום והככבים בלילה.

<.1> <1> והכונה בזה כי האופק יחלק לד' חלקים עם עגולת נכח הראש ועגול חצי היום אשר הוא בכלי ההבטה בקו ישר. <2> החלק האחד הוא שעם יתד השמים לצד מזרח ויקרא מזרחי דרומי. <3> והחלק שעם יתד הארץ לצד מזרח ויקרא מזרחי צפוני. <4> והחלק שעם יתד השמים לצד מערב ויקרא מערבי דרומי, <5> ושלמטה מערבי צפוני.

<.2> <1> ותרצה לדעת נכח איזה רביע מאלו הרבעים יראה הככב וכמה מעלות מהאפק בין נקודת אמצע המזרח והמערב ובין נקודת חתוך האופק עם עגולת הגובה העוברת על נכח הראש ועל איזה הככב בעת ההיא. <2> דע גובה השמש בעת ההיא ושים מעלת השמש בדמיון גובהו בגשרים, <3> אם בצד הגשרים המזרחיים בהיותו במזרח או המערביים בהיותו במערב.

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[1] The נ looks like a ג.
[2] Marginal note, hand eight: כ'.

⟨XX.3 The azimuth of the sun or any visible star or planet by day⟩

⟨1⟩ Look on which of the azimuthal lines the degree of the sun has fallen.[1] ⟨2⟩ If it is in the east, count how many azimuthal lines there are between the central point of the east [i.e., true east] and the ⟨azimuthal⟩ arc on which the sun is. ⟨3⟩ These are the degrees of the horizon between the centre of the east [i.e., true east] and the circle crossing the zenith and the star. ⟨4⟩ If it ⟨the star or planet⟩ is northern-eastern, it ⟨the azimuth⟩ is also northern-eastern with the same value. ⟨5⟩ If it is eastern-southern, it is ⟨so⟩ according to the corresponding degrees. ⟨6⟩ This works if the instrument is complete, but if it is medial, multiply by two the lines of the azimuth. ⟨7⟩ If it is tertial, ⟨multiply them⟩ by three. ⟨8⟩ The result is the number of the degrees on which the star is either eastern-northern or ⟨eastern-⟩ southern. ⟨9⟩ Do the same if the sun is western.

⟨XX.4 The azimuth of any fixed star by night⟩

⟨1⟩ You can know by this method the azimuth by night of any of the ⟨fixed⟩ stars engraved (59b) on the rete. ⟨2⟩ Place the pointer of the star among the almucantars according to its altitude and observe in which of the quadrants of the horizon it falls. ⟨3⟩ Do as ⟨you⟩ previously ⟨did⟩ in relation to the sun.[2]

⟨XX.5 The azimuth of the sunrise or of the rising of any fixed star⟩

⟨1⟩ When you want to know the azimuth of the sunrise or of the rising of any of the ⟨fixed⟩ stars engraved on the rete, place the solar degree or the star pointer on the line of the eastern horizon. ⟨2⟩ Pay attention to the azimuth that corresponds to it ⟨the rising degree⟩ in the quadrant in which the rising has fallen; it is the azimuth of the rising. ⟨3⟩ The same works for the azimuth of the setting and the corresponding quadrant, which is either northern or southern but on the western side. ⟨4⟩ When you understand the reason that we explain in the next chapter, you shall ⟨also⟩ understand ⟨the reason for⟩ this.[3]

[1] The Hebrew expression that denotes the azimuthal lines (קוי קדקוד) was coined and introduced in the Hebrew language by Abraham Ibn Ezra in the second and third versions of his text on the astrolabe (it is not in the first version); see Rodríguez-Arribas 2016, 94, 100–101, and 105.

[2] See Chapter XX.2.

[3] See Chapter XXI.2b. The calculation of azimuths is not relevant in Ibn Ezra's Hebrew astrolabe treatises. For Ibn Ezra's treatment of the azimuth, see MSS Paris BnF heb. 1053, f. 5b (first version, where he says that he does not explain them because they are not accurate), BnF heb. 1045, f. 189a (second version, where the same remark is made about their inaccuracy), and Günzburg 937, ff. 4b and 11b (third version). In Ibn Ezra's astrolabe texts the four quadrants of the horizon serve to find the direction in a very broad sense, but there is no actual use of the azimuthal lines in any of the three Hebrew treatises.

<.3> <1> וראה על אי זה מקוי הקדקד נפלה מעלת השמש <2> ואם הוא במזרח מנה {האופק}[1] כמה מקוי הקדקוד מנקודת אמצע המזרח עד {ש}הקשת[2] שהשמש בה, <3> והם שעור המעלות מהאופק שבין אמצע המזרח ובין העגולה העוברת על נכח הראש והככב. <4> ואם הוא צפוני מזרחי יהיה צפוני מזרחי בשעור ההוא. <5> ואם הוא מזרחי דרומי הנה הוא כשעור המעלו<ת> ההן. <6> וזה אם הכלי שלם אבל אם הוא חצי ערוך קוי הקדקד בשנים, <7> ואם שליש בשלשה <8> והעולה הם שעור המעלות שבהן הככב מזרחי[3] צפוני או דרומי <9> וכזה אם השמש מערבי.

<.4> <1> ובזה הדרך תוכל לדעת סומת הככב בלילה מהככבי<ם> המונחי<ם> ברשת. (59b) <2> שים שן הככב בגשרים בדמיון גובהו ותראה באי זה רובע מרבעי האופק נפל <3> ותעשה כמו שקדם בשמש.

<.5> <1> וכשתרצה לידע סומת עליית השמש או אחד מהככבי<ם> המונחים ברשת שים מעלת השמש או שן הככב על קו האופק המזרחי. <2> ועיין מה שיאות לו מן אלסמת ברובע שנפלה העלייה עליו והוא סמת העלייה. <3> ועל דמיון זה הסמת תהיה השקיעה בכמו[4] הרובע ההוא צפוני היה או דרומי לצד המערב. <4> וכשתבין הסבה שנבאר בשער הבא תבין סבת זה.

[1] Hand five wrote several dots above the word to mark it as a mistake (rightly). This word is misplaced here and unnecessary, even if the explanation is about certain divisions of the local horizon.
[2] Crossed out (rightly).
[3] Hand seven marked this word with two dots and the following with one to indicate an exchange in the order of the words, so that one reads צפוני מזרחי rather than מזרחי צפוני.
[4] Written ככמו.

⟨XXI⟩ CHAPTER: TO KNOW THE CENTRAL POINT⟨S⟩ EAST AND WEST, NORTH AND SOUTH IN ANY PLACE AND AT ANY TIME BY KNOWING THE AZIMUTH AND VICE VERSA; TO KNOW THE ALTITUDE OF THE SUN FROM THE AZIMUTH; AND TO KNOW THE SOLAR DEGREE FROM THE ALTITUDE AND THE AZIMUTH ALREADY KNOWN[1]

⟨XXI.1 Preliminary steps to find the four points of any horizon with the azimuthal lines of the astrolabe⟩

⟨1⟩ When you want this, find the azimuth of the sun for that moment. ⟨2⟩ Then place the front of the astrolabe on the ground with its back facing the sky; it will lay completely horizontal with respect to the plane of the horizon. ⟨3⟩ Place the extremity of the suspensory part to the south and count the number of the degrees of the azimuth, if the sun is in the east, from the point east in the quadrant of the horizon corresponding to the quadrant on which the azimuth is, or, if the sun is in the west, from the point west. ⟨4⟩ Place the end point of the alidade on the degree on which the counting ends. ⟨5⟩ You must do this immediately after having taken the azimuth, so that the ⟨value of the⟩ azimuth of the sun does not change noticeably.

⟨XXI.1a The four cardinal points of any horizon by day⟩

⟨1⟩ Then rotate [*lit.* move] the instrument in all the directions but keeping the alidade fixed, until (60a) the shadow of the sighting vane of the alidade falls directly on the alidade. ⟨2⟩ Then observe the line that extends from the beginning of the suspensory part to the angle of the earth [the lower meridian line on the back]; ⟨3⟩ it delimits for you the point north and the ⟨point⟩ south. ⟨4⟩ The line perpendicular to it delimits for you the central points of the east and the west in your location.

⟨XXI.2 Preliminary steps to find the four cardinal points of any horizon by night⟩

⟨1⟩ When you want to know this by night, take the altitude of any of the ⟨fixed⟩ stars engraved on the astrolabe and find its azimuth according to what was ⟨said⟩ before.[2] ⟨2⟩ Afterwards, turn the astrolabe and place the cane [i.e., fiducial line] of the alidade according to the corresponding degrees and the corresponding quadrant,[3] as you did by day with the azimuth of the sun.[4]

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[1] There is nothing on this (XXI.1–5) in Ibn Ezra’s Hebrew treatises on the astrolabe. However, Montalto describes in his astrolabe text a similar procedure to find the *qibla* by day and by night in which the astrolabe must be placed on the ground and oriented according to specific instructions; see MS Paris BnF heb. 1047, ff. 88b–89a. This procedure fits very well the gazetteer engraved as concentric circles on the womb of the mater in many Islamic astrolabes. This gazetteer displays the longitude and latitude of different cities as well as, very frequently, other coordinates to find the *qibla*, such as the inclination of the azimuth of the *qibla*, the direction of the azimuth of the *qibla* in relation to the four cardinal points of the compass, and the distance from Mecca. For these gazetteers and their forms, see King 1999.

[2] See Chapter XX.4.

[3] The fiducial line is the line running down the middle of the alidade.

[4] See Chapters XX.2 and XX.3.

<XXI> **שער לדעת** נקודות אמצע מזרח ומערב וצפון ודרום בכל מקום ובכל שעה מידיעת הסמת ו{כ}הפך[1] זה, ולדעת גובה השמש מפני הסמת ולדעת מעלת השמש מן הגובה והסמת הידועים.

<1.> <1> כשתרצה זה דע סמות השמש לעת ההיא. <2> אחר תשים פני האצטרולב על הארץ וגבו לצד השמים ויהיה מונח ביושר על שטח האופק. <3> ושים קצה התלייה לצד דרום ומנה מנקודה[2] המזרח ברובע האופק בדמיון הרובע שבו הסומת מעלות במספר מעלות הסמות אם השמש במזרח או מנקודת המערב אם השמש במערב. <4> ושים קצה המעצר על{ה}[3] המעלה שיכלה החשבון. <5> [וזה תעשה][4] במהירות ואחר שלקחת הסמת כדי שלא ישתנה סמות השמש שעור מורגש.

<1א.> <1> ואחר הניע הכלי ביושר לכל הצדדים והמעצר קיים עד שיפול (60a) צל לוח המעצר ביושר על המעצר. <2> ואז ראה אל הקו ההולך מראש התלייה עד יתד הארץ <3> והוא יגביל לך נקודת צפון ודרום; <4> והקו נצב עליו יגבי[ל][5] לך נקודות אמצע מזרח ומערב במקומך.

<2.> <1> וכאשר רצית זה בלילה קח גובה ככב מהככבים הרשומים באצטרולב ודע הסמת שלו לפי מה שקדם. <2> אחר הפך מאצטרולב ושים קנה המעצר על דמיון מספר אותם המעלות בדמיון הרובע ההוא[6] כמו שעשית ביום בסמת השמש.

[1] Crossed out (rightly).
[2] It should be מנקודת.
[3] Crossed out (rightly).
[4] Interlineal addition, hand two.
[5] Hand six seems to have marked this letter as a mistake, which it is not.
[6] Hand seven wrote two dots between the previous word and this to indicate a separation between the two words.

⟨XXI.2a The four cardinal points of any horizon by night⟩

⟨1⟩ After that, hold the astrolabe flat on your hand with its front facing the ground and with the sighting vane of the alidade,[1] the end point of which is on the number of these [almucantar] degrees, facing the star whose altitude you have measured. ⟨2⟩ Raise the astrolabe until you get a clear sight of the star through the two sighting holes of the sighting vanes. ⟨3⟩ The end point of the alidade ⟨must⟩ stand on the number on which you placed it. ⟨4⟩ When you have done this, place the astrolabe on your hand laying on its front and prevent it from moving to any side. ⟨5⟩ Observe the lines that intersect at right angles. ⟨6⟩ ⟨The line⟩ extending from the beginning of the suspensory part delimits for you the south and the north. ⟨7⟩ The ⟨line⟩ perpendicular to it ⟨delimits⟩ the east and the west, as you did with the azimuth of the sun.[2]

⟨XXI.2b Demonstration of this calculation⟩

⟨1⟩ The reason of this is that the sun always revolves in circles parallel to the equator, which change the day of its conjunction [of the sun] ⟨with the equator at the equinoxes⟩. ⟨2⟩ Hence the point of rising or setting always changes and it does not occur on the same point of the horizon. ⟨3⟩ When the sun moves along the circle of the beginning of Aries, the point of the rising on the horizon is then intermediate (60b) between the point of the horizon where the sun rises when it is in the beginning of Cancer and ⟨the point⟩ where it rises when it is in the beginning of Capricorn.

⟨4⟩ We consider the altitude circle on the back of the astrolabe as if it were the circle of the horizon in order to find this point and the three other points derived from it. ⟨5⟩ The centre of the instrument is like the point of the pole of the horizon. ⟨6⟩ When the sphere is projected onto the horizon, the azimuthal lines all become straight lines. ⟨7⟩ For this reason, when you place the alidade to represent the distance of the azimuth degrees from the eastern horizon, the ⟨fiducial⟩ line of the alidade represents the azimuth.

⟨8⟩ When you turn the alidade so that its shadow is aligned with it [the alidade], you know that the end point of the alidade is facing the same point of the horizon that the azimuth of the sun crosses. ⟨9⟩ The situation of the instrument represents the situation of the circle of the horizon and the alidade represents the azimuthal line that is not visible (בעינו). ⟨10⟩ The lines intersecting at right angles represent the azimuth crossing the central point⟨s⟩ of the east and the west and the central ⟨points⟩ of the north and the south,[3] which are the circle⟨s⟩ crossing the poles of the equator and the horizon. ⟨11⟩ This question is clear for the expert.

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[1] This (הדף מהמעצר, *lit.* “the sighting vane of the alidade”) clearly reflects the influence of a Romance language that has replaced the construct state (דף המעצר) characteristic of Semitic languages. However, I have detected no further examples of such Romance imprint on this text.

[2] See Chapter XX.1.

[3] As in XX.3, the meaning of the expression “central point” of the east, west, south, and north, is the corresponding true cardinal point.

<**2א.**> <1> אח<ר> כ<ך> החזק באצטרולב שטוח בידך הפנים שלו כנגד הארץ ונגד הדף מהמעצר אשר ילוה הקצה המונח על מספר המעלות ההם הככב אשר לקחת גובהו. <2> והגביה {~~הככב~~}[1] האצטרולב עד שתראה הככב מנקבי שני הדפין ראייה טובה <3> ויהיה קצה המעצר עומד על המספר אשר הושם עליו. <4> וכאשר עשית זה שים האצטרולב בידך על פניו מבלתי שתטה בו אל צד מהצדדים <5> וראה הקוים הנחתכים על זויות נצבות. <6> והנה ההולך מראש התלייה יגביל לך דרום וצפון <7> ואשר עליו על זויות נצבות מזרח ומערב כדרך שעשית בסומת השמש. {~~וס~~}[2]

<**2ב.**> <1> וסבת זה כי להיות שהשמש יסוב תמיד על עגולות נכחיו<ת> למשוה מתחלפות ביום מחברו. <2> לזה תהיה[3] נקודת הזריחה או השקיעה מתחלפת תמיד ואינה על[4] נקודה אחת מהאופק. <3> וכאשר סבב השמש בעגול ראש טלה הנה נקודת הזריחה באופק א[ז][5] היא אמצעי<ת> (60b) בין הנקודה מהאופק שיזרח ממנה השמש בהיותו בראש[6] סרטן ואשר יזרח ממנה בהיותו בראש גדי.
<4> והנה למצוא[7] זו הנקודה והג' נקודות האחרות המתחייבות ממנה אנו מדמים עגולת הגובה שבגב האצטרולב [כאילו][8] היא {ב}עגולת[9] האופק, <5> ומרכז הוא[10] הכלי כנקודת קטב האופק. <6> וכאשר השתטח[11] הכדור על האופק הנה ישובו קוי הקדקד כלם קוים ישרים. <7> ולזה כאשר שמת המעצר על דמיון מרחק מעלות הסמות ממזרח האופק הנה קו המעצר שבעצמו כדמיון הסמות.
<8> והנה כשסבבת המעצר עד השתוות צלו על יושרו אז ידעת שקצה המעצר הוא כנגד אותה הנקודה שסמות השמש עובר עליה מהאופק. <9> והנה הונח {עגול}[12] מצב הכלי כמצב עגול האופק והמעצר כדמיון קו הקדקד ההוא בעינו. <10> ונהיו הקוים המתחתכי<ם> על זויות נצבות כדמיון הסמות העובר על נקודות אמצע המזרח והמערב ואמצע הצפון והדרום שהוא העגול העובר על קטבי המשוה והאפק, <11> וזה הענין מבואר למבין.

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[1] Crossed out (rightly).
[2] Crossed out (rightly).
[3] The word is followed by an illegible isolated character with no apparent meaning; it must be a mistake of the copyist.
[4] Hand seven marked this word with two dots, the word is not a mistake.
[5] Interlineal correction, hand two. The original letter (ם) is crossed out by the same hand.
[6] ש written in superscript.
[7] א written in superscript.
[8] Interlineal correction, hand two. The original expression (כמו ש) is crossed out (rightly) by the same hand.
[9] Hand five indicated (rightly) the initial letter as a mistake (with a dot above and below the character).
[10] Hand seven marked this word with two dots and the following with one to indicate (rightly) an exchange in the order of the words, so that one must read הכלי הוא rather than הוא הכלי.
[11] The ת is a correction of the copyist of what he had previously written (ס).
[12] Hand seven marked this word with two dots and the following with one to indicate (rightly) an exchange in the order of the words, so that one must read מצב עגול rather than עגול מצב.

⟨XXI.3 Preliminary steps to find the azimuth of the sun using the cardinal points⟩

⟨1⟩ You want to know the azimuth of the sun by knowing the central point⟨s⟩ of the east, the west, the north, and the south. ⟨2⟩ If you understand the reason of what was said ⟨before⟩, it becomes clear that you need to perform the following ⟨steps⟩. ⟨3⟩ Take the instrument with its front downward and place the end point of the ⟨fiducial⟩ line ⟨of the alidade⟩ extending from the suspensory part ⟨of the astrolabe⟩ to the central point of the south. ⟨4⟩ The diameter perpendicular to this line is on the midpoint of the east and the west.

⟨XXI.3a The azimuth of the sun with the cardinal points of the horizon⟩

⟨1⟩ Move the alidade, while the instrument remains fixed, until ⟨the shadow of⟩ the sighting vane of the alidade falls directly onto the alidade. (61a) ⟨2⟩ When you do this, if the sun is eastern, observe in which of the quadrants of the horizon the end point of the alidade facing the east falls and how many degrees there are between the centre of the east and it. ⟨3⟩ This is the azimuth ⟨line⟩ where the sun is.

⟨XXI.4 The altitude of the sun with the azimuth⟩

⟨1⟩ If you want to know the altitude of the sun at a specific moment using the azimuth, observe the quadrant where the azimuth of the sun is on the ⟨latitude⟩ plate of your location. ⟨2⟩ Place the solar degree on the azimuth; the almucantar on which the degree of the sun falls is the altitude of the sun at that moment.

⟨XXI.5 The degree of the sun in the zodiac with the azimuth⟩

⟨1⟩ If you want to know the degree of the sun using the altitude and the azimuth ⟨already⟩ known, observe the almucantar on which the sun is and which point of it [the almucantar] this azimuth intersects. ⟨2⟩ Also find in which half of the zodiac the sun is, if it is in the half from Cancer to Sagittarius or in ⟨the half from⟩ Capricorn to Gemini.[1] ⟨3⟩ Move the rete so that it crosses the whole half of the zodiac—on which the sun is—on the side of that azimuth. ⟨4⟩ The zodiac degree crossing the point at which the azimuth intersects the almucantar of the altitude of the sun is the degree of the sun that day.

[1] These two halves of the zodiac are symmetrically divided by the axis of the solstices, so that all degrees equidistant from the two solstices are equivalent and have identical "power." Abraham bar Ḥiyya in his *Sefer ḥešbon* calls these degrees (for instance, 10º of Capricorn and 20º of Sagittarius) *maʿalot maskimot ʿal koaḥ eḥad* ("degrees that agree according to one power"); see Millás Vallicrosa 1959, 101 (Spanish) and 109 (Hebrew).

<3.> <1> **ואם** תרצה לדעת סמת השמש מצד ידיעת נקודת אמצע המזרח והמערב צפון ודרום, <2> אם תבין סבת מה שנאמ<ר> יתבאר לך שצריך שתעשה כן. <3> תקח הכלי ופניו למטה ושים נקודת קצה הקו המתחיל מראש התלייה על נקודת אמצע הדרום. <4> והקטר הנצב על זה על נקודות אמצע מזרח ומערב.

<3א.> <1> והניע המעצר והכלי קיים עד שיפול דף המעצר על המעצר ביושר. (61a) <2> וכאשר עשית זה אם השמש במזרח ראה באי זה מהרבעי<ם> מהאופק נפל {ה}קצה[1] המעצר שאצל הצד המזרחי וכמה מעלות מאמצע המזרח עדיו, <3> והוא הסמת שהשמש בו.

<4.> <1> **ואם** תרצה לדעת גובה השמש לעת ההיא מפני הסמת[2] ראה בלוח ארצך הסמת ההוא ברביע שהוא בו. <2> ושים מעלת השמש בסמת והגשר שתפול מעלת השמש עליו הוא גובה השמש לעת ההוא.

<5.> <1> **ואם** רצית לדעת מעלת השמש מצד הגובה והסמת הידועים ראה הגשר שהשמש בו על איזו נקודה ממנו נחתך עם הסמת ההוא. <2> גם דע השמש באי זה מהמזלות[3] חצי הוא אם הוא מהחצי שמסרטן עד קשת או שמגדי עד תאומים. <3> והניע הרשת שיעבור כל החצי מהמזלות שהשמש בו בצד הסמת ההוא, <4> והמעלה מהמזלות שתעבור על נקודת[4] חתוך הסמת עם הגשר שגובה השמש בו היא מעלת השמש ליום ההוא.

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[1] Crossed out (rightly).
[2] ת written in superscript.
[3] Hand seven marked this word with two dots and the following with one to indicate (rightly) an exchange in the order of the words, so that one must read חצי מהמזלות rather than מהמזלות חצי.
[4] ת written in superscript.

XXII CHAPTER: TO KNOW THE AZIMUTH CROSSING YOUR ZENITH AND THE ZENITH OF ANOTHER LOCATION; TO KNOW THE LONGITUDE AND THE LATITUDE; AND HOW YOU MARK ON YOUR LOCATION THE LINE THROUGH THE ZENITH OF THAT LOCATION[1]

⟨XXII.1 The azimuth crossing one's zenith and the zenith of another location⟩

⟨1⟩ This what the Muslims always want to know is called *al-qibla*, i.e., the alignment of your location with another specific location.[2] ⟨2⟩ The meaning is the arc line crossing the surface of the terrestrial sphere that corresponds to the arc ⟨of the great circle⟩ of the sphere crossing your zenith and the zenith of the ⟨other⟩ location. ⟨3⟩ When you want this, find the latitude of the ⟨other⟩ location by counting on the meridian line—between the point of the equator and the north— the almucantars (61b) corresponding to the number of the latitude of the ⟨other⟩ location. ⟨4⟩ This location is usually north, for the inhabited part of the world is in the north. ⟨5⟩ If it ⟨the other location⟩ is in the south, count the degrees of that latitude from the equator to outside and make a mark on the meridian line.

⟨6⟩ Afterwards, turn the rete until a part of it—either any star pointer or any degree of the zodiac—falls on this mark. ⟨7⟩ Mark this position on the rete and find the degrees between the longitude of your location and the longitude of the other location. ⟨8⟩ If it is east of your location, move the pointer of the beginning of Capricorn [the almuri or indicator] from its position eastward ⟨by⟩ these number of degrees, or if it ⟨the other location⟩ is west ⟨of your location, move the almuri⟩ westward. ⟨9⟩ After doing this, note on which of the azimuthal lines the mark that you made on the rete has fallen. ⟨10⟩ It is the azimuth passing through the zenith of your location and through the zenith of the other location.

⟨XXII.2 The quadrant of the azimuth that you have found⟩

⟨1⟩ Look in which of the quadrants this azimuth is ⟨located⟩ and its distance from the centre of the east or the west. ⟨2⟩ The location you are looking for is ⟨placed⟩ at these number of degrees, either southern-eastern with respect to you or northern-eastern, and so on. ⟨3⟩ The reason of this is clear; the distance from the equator of the point that you marked on the meridian line is the latitude of the place. ⟨4⟩ If the plate was constructed for your location, it is apparent that this point has to be the point of the zenith.

⟨XXII.2a Demonstration of this calculation⟩

⟨1⟩ If it [the point marked on the meridian line] intersects a circle parallel to the equator crossing the pole of that horizon, it crosses the meridian line of your location at a point that corresponds to the point you marked.

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[1] There is nothing about the calculation of the *qibla* (XXII. 1–4) in Ibn Ezra's Hebrew treatises on the astrolabe; however, as noted, Montalto explains how to find it in his astrolabe treatise; see MS Paris BnF heb. 1047, ff. 88b–89a.

[2] The presence of the *qibla* in this Hebrew treatise suggests that either the treatise was "inspired" by an Arabic text on the astrolabe (Arabic treatises on the subject always discuss the *qibla*) or the concept was so widespread in Moses' surroundings (a Muslim society) that he felt compelled to integrate this common calculation, devoid of its religious connotations, into the context of azimuth calculations, of which the *qibla* is a special case.

<XXII> **שער**[1] **לדעת** סמת העובר מנכח ראשך על נכח [ראש][2] ארץ אחרת, יד[י]עת[3] האורך והרחב ואיך תרשום בארצך קו יעבור על נכח ראש המקום ההוא.

<1.> <1> והוא אשר ירצוהו הישמעאלים למצוא תמיד ויקרא אלקבלא כלומ<ר> הנכחות שבין מקומך למקום מה. <2> והכוונה בקו קשת עובר על שטח כדור הארץ מקביל לקשת שבכדור העובר על נכח ראשך ונכח ראש המקום ההוא. <3> כשתרצה זה דע רוחב הארץ ההיא ומנה בקו חצי היום מהגשרים לצד צפון מנקודת (61b) המשוה במספר רוחב המקום ההוא. <4> וזה להיות הארץ ההיא צפונית כי היישוב בצפון. <5> ואם יתכן שתהיה בדרום, מנה כמספר הרחב ההוא מהמשוה ולחוץ ורשום סימן בקו חצי היום.

<6> אח<ר> כ<ך> סבב הרשת עד שיעבור דבר ממנה רצו<ני> או שן ככב או מעלת[4] מהמזלות על הסימן ההוא. <7> ורשום ברשת על המקום ההוא ודע שעור מה שבין ארך ארצך וארך הארץ ההיא[5] מהמעלות. <8> ואם היא מזרחית לארצך הניע השן שעם ראש גדי לצד מזרח בשעור המעלות ההן מן המקום שהוא או לצד מערבי אם היא מערבית. <9> וכאשר עשית זה [ראה על אי זה][6] מקוי הקדקוד נפל הסימן שרשמת ברשת[7], <10> והוא הסמת העובר על נכח ראשך ונכח ראש אנשי המקום ההוא.

<2.> <1> וראה הסמת ההוא באי זה מהרביעים הוא וכמה מרחקו מאמצע המזרח או המערב, <2> וכשעור המעלות ההן תהיה הארץ המבוקשת אם דרומית מזרחי<ת> לך או צפונית מזרחית וזולת זה. <3> וסבת זה מבוארת וזה כי הנקודה שרשמת בקו חצי היום מרחקה מהמשוה כשעור[8] רוחב המקום. <4> מבואר שבזאת[9] הנקודה היה ראוי להיות נקודת הראש אלו היה הלוח בנוי על הארץ ההיא.

<2א.> <1> ולו העברת עגול נכחי למשוה עובר על קטב {~~הארץ~~}[10] האופק ההוא יעבור בקו חצי יום מקומך בנקודה שהיא כדמיון הנקודה שרשמת.

[1] Marginal note, hand eight: כ"ב.
[2] Interlineal addition, hand two.
[3] The second י written in superscript.
[4] It should be מעלה.
[5] י is a correction of a ו previously written.
[6] Marginal addition, hand two.
[7] ת written in superscript.
[8] Written בשעור.
[9] Marginal note, hand 9: נ<וסח> א<חר> שבאותה. This is an intriguing remark that witnesses the existence of, at least, another copy of Moses ben Abraham's text on the astrolabe. In addition, it shows that the author of this note compared the two versions he read.
[10] Crossed out (rightly).

⟨2⟩ As the arc of longitude changes from one location to another, it [the arc of longitude] is estimated with the arc⟨s⟩ of the equator; these arcs ⟨of the equator⟩ delimit equal arcs radiating from the pole of the equator and each of them crosses (62a) the zenith of the ⟨two⟩ location⟨s⟩ determining ⟨the degrees of longitude⟩ between them. ⟨3⟩ These arcs become straight line⟨s⟩ in the plane.

⟨4⟩ If we move the rete with the difference in degrees between the ⟨two⟩ longitudes indicated on the scale [*lit.* circle] of the limb, the point that you marked on the rete crosses the same number of degrees in the circle—parallel to the equator—crossing the pole of the location and the meridian circle of your location, and cross it at the point that you marked on the circle of the equator . ⟨5⟩ Also the line extending from the centre of the equator and crossing the point that you marked on the arc is like the arc extending from the pole of the equator and crossing the pole of that location. ⟨6⟩ The pole of this place has to fall on this point on the plane according to the experts of the craft. ⟨7⟩ According to this (אם כן), the azimuth crossing it [the pole of the place] on the plane represents the azimuth crossing the invisible (בעינו) sphere.

⟨XXII.3 The degrees of the difference between the two zeniths⟩

⟨1⟩ If you want to know the degrees between your zenith and the zenith of another location, observe on which almucantar number the mark ⟨you made⟩ on the rete has fallen. ⟨2⟩ We subtract ⟨it⟩ [the degrees indicated by the almucantar] from 90 ⟨and get the altitude of the pole in your location. 3 We do the same for the latitude of the other location to find the altitude of its pole. 4 Then we find the difference in degrees between the two altitudes of the pole⟩[1] and the remainder is the degrees between your zenith and the zenith of the ⟨other⟩ location.

⟨XXII.4 The *qibla*⟩

⟨1⟩ If you want to know the *qibla*, find the ⟨central⟩ points east, west, north, and south at your location. ⟨2⟩ Put the instrument on the ground with its front downwards and the top of the suspensory part aligned with the point south. ⟨3⟩ Move [*lit.* place] the alidade on the degrees of the altitude scale to the number of the azimuth that you found, either ⟨in⟩ the eastern or the western side [*lit.*, point]. ⟨4⟩ The line that the alidade directly indicates is the direction in longitude of your location that you were seeking.

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[1] I have completed this passage with sentences that are not in the Hebrew text in order to make sense of the explanation.

<2> ומפני שהקשת שבין מקום מקום מתחלף בארך למקום הוא אמנם ישוער עם הקשת מהמשוה[1] שיבדילוה הקשתות השוות[2] היוצאות מקטב המשוה ועוברת (62a) כל אחת על נכח ראש המקומות כמה[3] שביניהם; <3> ואלו הקשתות[4] בשטח ישובו קו ישר.

<4> הנה כאשר הנענו הרשת בשעור מה שבין הארכין מן העגולה שבתא בדמיונו עברה הנקודה שרשמת ברשת העגולה הנכחית למשוה העוברת על הקטב המקום ועל עגול חצי היום של מקומך בנקודה שרשמת מן עגול המשוה. <5> גם כן הנה הקו היוצא ממרכז המשוה העובר בנקודה שרשמת בקשת הוא בדמיון הקשת שיוצאת מקטב המשוה ועובר על קטב המקום ההוא. <6> ובנקודה ההיא ראוי שיפול קטב המקום ההוא בשטח למבינים [ה]מלאכה[5]. <7> הנה אם כן הסמת העובר עליו בשטח הוא בדמיון הסמת העובר בכדור בעינו.

<3.> <1> **ואם** רצית לדעת המעלות שבין נכח ראשך לנכח ראש המקום ההוא ראה הסימן שברשת על אי זה מספר מהגשרים נפל. <2> וחסרנו מצ' והנשאר הוא מה שבין נכח ארצך לנכח ראש המקום ההוא.

<4.> <1> וכאשר רצית לדעת אלקבלא דע נקודות מזרח ומערב צפון ודרום בארצך, <2> והניח הכלי ופניו בארץ וראש התלייה על נקודת הדרום. <3> ושים המעצר ממעלות עגולת הגובה כשעור הסמת שמצאת אם מנקודות המזרח [א]ו[6] המערב <4> והקו שהוא ביושר הבריח הוא נכחות הארץ הדרושה מארצך.

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[1] ה written in superscript.
[2] Crossed out on the manuscript, but the word is right, so I keep it.
[3] Written במה.
[4] ת written in superscript.
[5] Interlineal correction, hand two. The initial letter (ב) is crossed out.
[6] Interlineal addition, hand two. Hand nine marked with two dots the place of its insertion.

XXIII CHAPTER: TO KNOW THE SHADOW FROM THE ALTITUDE OF THE SUN AND VICE VERSA ⟨USING A GNOMON AND USING AN ASTROLABE⟩[1]

⟨XXIII.1 Astrolabe: The shadows—Definitions⟩

⟨1⟩ First know that the craft ⟨of the astrolabe⟩ uses two shadows. ⟨2⟩ One is called the straight shadow and the other the inverted shadow.[2] (62b) ⟨3⟩ The straight shadow, ⟨which is parallel to⟩ the plane of the horizon [i.e., to the horizontal diameter on the back of the astrolabe], starts from the vertical line (עמוד) that is perpendicular to it [the plane of the horizon]. ⟨4⟩ The inverted shadow is perpendicular to this line (עמוד) [the line of the straight shadow] and starts from the other line (עמוד) [the horizontal] that is perpendicular to the vertical one, for this reason it is called inverted. ⟨5⟩ We are going to completely explain how this question works. ⟨6⟩ As we have not seen any text ⟨dealing⟩ with this ⟨question⟩, we will present these shadows in a demonstrative way.[3]

⟨XXIII.2 Gnomon: The straight shadow⟩

⟨1⟩ We say that these shadows work as follows. ⟨2⟩ The straight shadow takes place from the moment the sun rises above the horizon. ⟨3⟩ It [the shadow] advances and spreads over a long distance on the surface of the earth until one finds that, when the altitude of the sun above the earth is one degree, the measure [*lit.* the divisions] of the shadow of a gnomon placed perpendicularly to the surface of the horizon and divided into 12 parts is 687 digits 26 minutes.[4] ⟨4⟩ We explain later more about how one knows this.

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[1] There is nothing about shadows with a gnomon or calculating the altitude or azimuth of the sun with a gnomon (Chapter XXIII.1–8 and XXIV, respectively) in Ibn Ezra's Hebrew treatises, but Montalto explains how to calculate the height, depth, and distance of an object (i.e., land survey applications of the shadow square) with an additional tool that is not an astrolabe (a triangle made of an unspecified material); see MS Paris BnF heb. 1047, ff. 90b–91a. Unlike Moses ben Abraham, Montalto does not use trigonometrical calculation, just ratios as does A. Ibn Ezra in his land surveying calculations, although Ibn Ezra uses it at the end of the second version of his astrolabe text, while explaining how to correct planetary tables; see MS Paris BnF heb. 1045, f. 196a.

[2] In Latin texts, these are usually known as the *umbra extensa* or *umbra recta* ("extended shadow" or "right shadow") and the *umbra versa* ("reversed/inverted shadow"). In the shadow square on an astrolabe the "straight shadow" runs horizontally from the vertical axis, but below the horizontal axis, while the "inverted shadow" runs down from the horizontal axis to the end of the "straight shadow." This forms a square and the corner where the two shadows meet is diametrically opposite the corner of the square at the centre of the astrolabe.

[3] This seems to imply that he was following a standard or pre-established arrangement of the chapters and at this point he departs from this plan to explain the topographical uses of astrolabes that must not have been properly explained in the sources he consulted when writing his astrolabe treatise.

[4] See Diagram 1: The gnomon (*HṬ*) is divided into 12 parts/digits, the solar ray is *ZṬB*, and the angle at *Z* is 1º. When this angle is 1º its cotangent is 57,29 = *ZH*/*HṬ*, being *HṬ*=12. Then the cotangent of 1/12 of *HṬ* is *ZH*/(*HṬ*/12) = 12(*ZH*/*HṬ*). As *ZH*/*HṬ*=57,29, so 12*cot* 1º = 687;28,46digits. As 26/60 = 43,3333, Moses ben Abraham deviation with respect to the exact value is only 0.0067%. One "digit" is here equivalent to one "part" and one "minute" is 1/60 of a digit.

<XXIII> שער[1] לדעת הצל מן גובה השמש והפך זה.

<1.> <1> דע תחלה כי ישתמשו בזו המלאכה בשני צללים, <2> האחד יקרא צל ישר והשני צל הפוך. <3> הצל (62b) הישר הוא המתחדש על שטח האופק[2] מצד העמוד הנצב עליו על זוית נצבת. <4> וההפוך הוא הצל הנופל על זה העמוד מעמוד אחר תקוע בראשו עומד עליו על זוית נצבתו לזה יקרא הפוך. <5> והנה נבאר מנהג הענין הזה הנה בשלמות, <6> כי לא ראינו בזה מאמר עדיין יעמידנו על מנהג הצללים האלו בדרך מופתי.

<2.> <1> ונאמר כי מנהג הצללים האלו, <2> הוא שהצל הישר יהיה בעת זריחת השמש על הארץ, <3> הולך ומשתטח על שטח הארץ למרחק רב עד שמצאו בהיות גובה השמש על הארץ מעלה אחת שבחלקי<ם> שהעמוד הזה הנצב על שטח האופק יחלק לי"ב חלקים יהיה צלו שעל הארץ תרפ"ז אצבעות כ"ו דקים. <4> ונבאר עוד למטה איך ידעו זה.

[1] Marginal note, hand eight: כ"ג.
[2] It should be הוא המתחדש נכוחי לקו הישר rather than הוא המתחדש על שטח האופק.

⟨XXIII.3 Gnomon: The evolution of the shadow until midday⟩

⟨1⟩ The straight shadow ⟨works⟩ in this ⟨way⟩: Every time the sun goes up above the earth, its shadow diminishes until the sun reaches its maximum altitude, which happens when it is in the [meridian].[1] ⟨2⟩ In ⟨those⟩ locations where the sun passes through the zenith,[2] the gnomon does not display any shadow at all. ⟨3⟩ When the altitude of the sun is 45 degrees, the shadow of any object is equal to its height, as we are going to explain.[3] ⟨4⟩ The rule (משפט) of the inverted shadow is the opposite to it ⟨the straight shadow⟩.

⟨XXIII.4 Gnomon: The evolution of the shadow according to the daily solar path⟩

⟨1⟩ At the moment of sunrise it [the gnomon] has no shadow at all, for the upper end point ⟨of the gnomon⟩ is aligned with the ray of the sun.[4] ⟨2⟩ When the sun increases its altitude above the horizon, its shadow [decreases][5] until the shadow is equal to the gnomon (עמוד) at the moment when the sun reaches an altitude of 45 degrees ⟨and keeps decreasing until reaching its minimum at noon⟩. ⟨3⟩ Then ⟨from the meridian⟩ this shadow increases until, when the sun reaches its ⟨minimum⟩ altitude [i.e., at one degree before sunset], the [straight][6] shadow is 687 ⟨digits⟩ 26 minutes, which are the 12 ⟨parts⟩ of the gnomon.

[1] "Meridian" is my correction of "zenith," written in the manuscript. The sun reaches the exact zenith only twice per year at locations on earth between the Tropics of Cancer and Capricorn and straight shadows only occur when the sun can reach the zenith. The less precise use of the word "zenith" to indicate the point where the sun is highest in the sky (rather than precisely overhead) on any particular day (i.e., at noon, when it crosses the meridian) is common in medieval astronomical texts.

[2] The sun is exactly in the zenith (i.e., directly overhead when it crosses the meridian) at the equator at the equinoxes. On other days of the year at the equator the sun will not rise so high–it will only reach 66.5 degrees altitude at the solstices. On the other hand, for latitudes within 23.5 degrees of the equator the sun will reach the zenith on days other than the equinoxes. The point being made is that a gnomon will not only have no shadow to the left or right when the sun is at the true zenith, but also it will not have a shadow in front or behind.

[3] When the sun is at 45 degrees, the shadow forms a right-angle isosceles triangle and therefore the length of the shadow equals the height of the perpendicular gnomon. The object is standing perpendicular to the ground.

[4] Then the straight shadow would start to be infinite, but decreases as the sun rises until the shadow is 687 digits 26 minutes when the sun is one degree above the horizon, as the author has previously explained in Chapter XIII.2.

[5] "Decreases" is my correction of "increases," written in the manuscript.

[6] "Straight" is my correction of "inverted," written in the manuscript. It should be "straight," given that the inverted shadow tends to zero as the sun sets.

<.3> <1> והנה בזה הצל הישר, כל עוד שיגבה השמש על הארץ יתמעט צלו עד בוא השמש לתכלית גבהו והוא בהיותו בנקודת נכח הראש[1], <2> וזה במקומות שיעבור השמש על נכח ראשיהם ואז לא יהיה לעמוד צל כלל. <3> ובהיות גובה השמש מ"ה מעלות ישתוה צל כל דבר לגובהו כמו שנבאר. <4> ומשפט הצל ההפוך להפך זה.

<.4> <1> כי בעת הזריחה לא יהיה לו צל כלל כי ראשו כנגד נצוץ השמש. <2> וכשיוסיף השמש שיגבה על האופק ילך הצל הזה [הולך][2] והוסף[3] עד[4] שבהיות השמש במעלת מ"ה {~~מהככבי~~}[5] [מהגובה][6] ישתוה הצל אל העמוד, <3> ויוסיף להארך הצל הזה עד שבהיות השמש בתכלית גבהו יהיה הצל ההפוך[7] הזה תרפ"ז כ"ו חלקי<ם> שיש י"ב באורך העמוד,

[1] בנקודת נכח הראש should be בחצי היום or בחצי השמים.
[2] Written הלוך. Hand seven, marked it with two dots (followed by one dot), indicating that it should be read הולך.
[3] It should be יתמעט.
[4] ד is a scribal correction of the group וד, written first.
[5] Crossed out (rightly). Hand nine marked the word with two dots to indicate the insertion of a marginal note that replaced it.
[6] Marginal note, hand nine.
[7] It should be הישר.

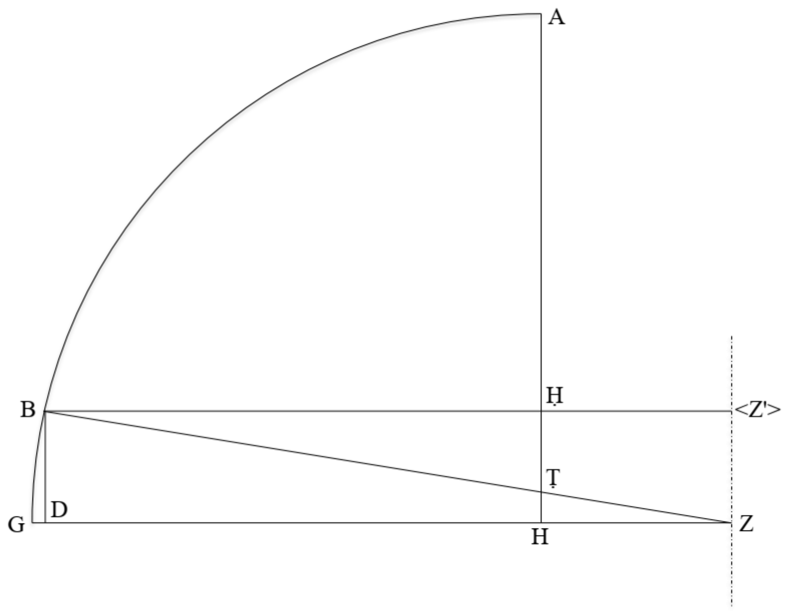

Diagram 1 (MS Paris BnF heb. 1030, f. 63a, on the upper part of the left margin and within a space left blank by the scribe). The ray of the rising sun (*BṬZ*) is projected on the ground at the endpoint of a gnomon (*ṬH*) that projects its shadow (*ZH*) on the ground. *H* is the centre of the world and the location where this is taking place, which can be any place in the Earth, for the size of the Earth is so small in relation to the size of the solar body, that it is considered to be a point on the projection. The lines of the manuscript drawing were made with brownish ink and the letters with bright red ink. Letter *Z′* has been added to facilitate the description and calculation, but it is not found in the manuscript.

⟨XXIII.4a Demonstration of the straight shadow: Diagram 1⟩

⟨1⟩ The relation of the inverted shadow (העמוד ההפוך) to the zenith point of the horizon is like the relation of the ⟨straight⟩ shadow to the east or west point (63a) of the horizon, ⟨2⟩ and this is how these shadows work. ⟨3⟩ To clarify, we copy[1] how one knows the length of the shadow, either straight or inverted, for any degree of altitude. ⟨4⟩ Let us consider the quadrant of the circle of altitude *ABG*, ⟨in which⟩ *A* is the point of the zenith, *G* is the point east, *H* is the centre of the earth, and *HṬ* is the gnomon.

[1] Moses ben Abraham uses here the Hebrew word (ונעתק) meaning “to copy” or “to translate”; this means that he is now copying/translating, something he was not doing before. This is confirmed because, starting here, Abraham’s text changes and becomes much more geometrical (he quotes Euclid and works out Euclidean proofs) than the rest of the text.

DIAGRAM 1: MS Paris BnF heb. 1030, f. 62b. Photo courtesy of the Bibliothèque nationale de France

<4א.> <1> כי יחס מצב העמוד ההפוך אל נקודת נכח ראש האופק כיחס מצב העמוד אל נקודת מזרח או מערב (63a) האופק, <2> זהו מנהג הצללים האלו. <3> ונעתק לביאור איך יודע אורך הצל בכל מעלה מהגובה בין מהישר בין מההפוך. <4> ונניח רביע עגול הגובה א'ב'ג' וא' נקודת נכח הראש וג' {נקודת}[1] נקודת המזרח ומרכז הארץ ה' והעמוד ה'ט'.

[1] Hand five indicated it as wrong (rightly) with a dot on top of each of the three last characters.

⟨5⟩ The Earth is ⟨very⟩ small in relation to the body of the sun and has no perceptible size, so on the projection (המקיש) it is considered smaller than a point.[1] ⟨6⟩ Thus, when the sun rises, even just one minute, the ⟨solar⟩ ray goes through point Ṭ of the projection (מהמקיש) and determines an acute angle. ⟨7⟩ For this reason, the ray ends touching the plane of the horizon [at *Z*] on the other side of the gnomon.

⟨XXIII.4b Practical example: Diagram 1⟩

⟨1⟩ We put the altitude of the sun one degree above the earth, which is arc *GB*, and then one ray of the sun, ⟨line⟩ *BṬ*, ends at point *Z* on the plane of the horizon. ⟨2⟩ Triangle *ZHṬ* is formed and line *BD*, which is the sine of arc *BG*—or the opposite ⟨side to its angle⟩, is drawn.[2] ⟨3⟩ Take *BḤ*—the sine of arc *AB*—which is left to complement the ⟨solar⟩ altitude ⟨up to the zenith⟩.

⟨4⟩ Triangle *ZHṬ* is formed by the line of the ⟨solar⟩ ray [*BṬZ*] and the ⟨projected⟩ shadow [*HZ*]. ⟨5⟩ Due to the smallness of the projections and their shadows in relation to the sky, triangle *ZHṬ* is considered like a point. ⟨6⟩ For this reason, there is no perceptible ⟨difference in⟩ value at all ⟨either⟩ between line *ZD* and ⟨line⟩ *HD*, ⟨or between⟩ line *ḤB* and line *HD*,[3] because the angle at *Ḥ* [*BḤṬ*] is right like the angles at *H* [*ṬHZ*] and at *D* [*BDZ*].

⟨7⟩ Surface [*BDH*][4] has a right angle ⟨at point *D*⟩. ⟨8⟩ For this reason the two opposite sides ⟨of the parallelogram that it forms, *BDHḤ*⟩ are equal [i.e., *DB* and *HḤ*], as it is clear from Book 1 of Euclid, Proposition 34.[5] ⟨9⟩ And for this reason ⟨too⟩, lines *ḤB* and *HD* are ⟨also⟩ equal. ⟨10⟩ It is apparent that triangles *ZHṬ* ⟨and⟩ *ZBD* are similar.

[1] See III.4, 3 above.

[2] Al-Battānī tabulates the sine for the same arguments that Ptolemy uses for the chords. The sine of an arc is in al-Battānī's terminology "the semichord of the double arc," an expression that is close to Moses ben Abraham's expression throughout his treatise, who uses *meitar meḥuṣah* (*lit.* "semi-chord") to denote sine; see Nallino 1899–1907, 3:15 (l. 12), n. 146. Abraham bar Ḥiyya explains this concept in his *Sefer ḥešbon mahaleḵot ha-koḵavim*; see Millás Vallicrosa 1959, 30 (Spanish), 122 (table of semichords from 1 to 90 degrees in Spanish), and 15 (Hebrew); and uses it (*meitar meḥuṣah*) several times, see ibid. 4, 15, 16–17, 19–20, 24, and 34 (Hebrew text).

[3] There is a real approximation here ($HD \sim ZD$) and, although it seems odd that it is associated with an exact identity in the diagram ($ḤB = HD$), the author has explained that the difference is of no importance because of the tiny size of triangle *ZHṬ*.

[4] "*BDH*" is my correction of "*BH*," written in the manuscript.

[5] Heath 1926, 1:323: "In parallelogrammic areas the opposite sides and angles are equal to one another, and the diameter bisects the areas." For the medieval tradition of Euclid in Hebrew, see Lévy 1997a and 1997b; and Elior 2021.

<5> והנה לקטן הארץ אצל גוף השמש ובלתי היות לה שעור מורגש וכ<ל> ש<כן> אצל המקיש שהוא נחשב קטן מנקודה. <6> לכן בזרוח השמש אפי<לו> דק יהיה הנצוץ עובר על נקודת ט' מהמקיש ומקיף עמו בזוית נדוחת. <7> ולכן יכלה הנצוץ ויפגוש שטח האופק מצד השני מהעמוד.

<4ב.> <1> ונניח גובה השמש מעלה אחת על הארץ והיא קשת ג'ב', ויצא נצוץ ב'ט' מהשמש ויכלה אל נקודה ז' משטח האופק. <2> ויתחדש משלש ז'ה'ט' ונוציא קו ב'ד' והוא מיתר מחוצה או נכחות לקשת ב'ג'. <3> וקח ב'ח' מיתר מחוצה לקשת א'ב' הנשארת לתשלום הגובה.

<4> והנה נתחדש מהעמוד הנצוץ והצל משלש ז'ה'ט', <5> ולקוטן המקישי<ם> וצלליהם אצל השמים יחשב כל משלש ז'ה'ט' כנקודה. <6> ולזה לא יהיה {~~ה' ושאצל~~}[1] {ד'}[2] {~~הנה שטח ב'ה'~~}[3] שעור מוחש כלל בין קו ז'ד' לקו ה'ד' וקו ח'ב' שוה לקו ה'ד' מפני שהזויות שאצל ח' נצבות הזויות שאצל ה' ושאצל ד'.

<7> הנה שטח ב'ה'[4] נצב הזויות, <8> ולזה הוא שוה הצלעות הנכחיות כמבואר מהמאמ<ר> הא' מאקלידס תמונת ל"ד <9> ולזה קוי ח'ב' ה'ד' שוים. <10> והנה מבואר שמשלשי ז'ה'ט' ז'ב'ד' מתדמים {וזה}[5] {~~מחוצה לגובה השמש הידוע מלוח הקשתות מצד~~}[6].

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[1] Crossed out (rightly).
[2] This letter should be also crossed out because it does not make sense in the context.
[3] Crossed out (rightly).
[4] It should be ב'ד'ה'.
[5] This word before the crossing out group of words is repeated on the next folio.
[6] These words are crossed out (rightly).

(63b) ⟨11⟩ This implies that the angle at *Z* is common ⟨for two triangles, *ZHṬ* and *ZBD*⟩ and the right angle at *D* is equal to the angle at *H*.
⟨12⟩ According to this, *BD*, which is the sine of the arc of the solar altitude found from the table of arcs, is known because its ratio to line *ZD* is as its ⟨ratio⟩ to line *HD*.[1] ⟨13⟩ This found, ⟨the ratio of line *BD*⟩ to line *ḤB*, whose arc is also known, is as the ratio of the gnomon *HṬ*, which is known to be 12, to its unknown shadow, which is *ZH*. ⟨14⟩ As explained in Euclid's ⟨Book⟩ 6, ⟨Proposition 16⟩,[2] four values [i.e., four line segments] relate the multiplication of *HA* by *BD* with the multiplication of *HB* by *BG*.[3] ⟨15⟩ We multiply line *HṬ*, which is the gnomon and is known,[4] by line *HD* [= *ḤB*], which is ⟨also⟩ known.[5] ⟨16⟩ We divide the result by line *BD*, which is ⟨already⟩ known, and what results is line *ZH* [i.e., the shadow of the gnomon], which was unknown.[6]

⟨XXIII.5 The altitude of the sun and the shadows are interrelated⟩

⟨l⟩ By this method, one can know the altitude of the sun at any moment if one knows the straight shadow at that moment. ⟨2⟩ For this we multiply the sine of the ⟨arc of the⟩ complement of the altitude [*BḤ*] by the length of the gnomon [*HṬ*]. ⟨3⟩ We divide the result by the sine of the arc of the altitude and the result is the shadow that is unknown.[7]
⟨4⟩ It becomes clear that when the altitude of the sun is 45 degrees the straight shadow is equal to the other shadow. ⟨5⟩ This is because the sine of the arc of altitude is equal to the sine of the complementary arc of altitude [= 90º-solar altitude].[8]

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[1] Because, as previously said, *HD* ∼ *ZD*.
[2] Heath 1926, 2:221: "If four straight lines be proportional, the rectangle contained by the extremes is equal to the rectangle contained by the means; and, if the rectangle contained by the extremes be equal to the rectangle contained by the means, the four straight lines will be proportional."
[3] The meaning of this sentence ("four values ... *HB* by *BG*") is not clear (for instance, *BG* is an arc, not a line). We could understand that the proposition moves on from the four line segments in proportion that were previously identified (*BD*/*ḤB* = *HṬ*/*ZH*) to the calculation of *ZH* = (*HṬ*·*HD*/*BD*). For us, this is just a rearrangement of the ratios, with the substitution *ḤB* = *HD*. But to justify it geometrically we need to know that *BD*/*ḤB* = *HṬ*/*ZH* implies that rectangles *ZH*·*BD* = *HṬ*·*HD*. The text might also argue that *ḤB* is known, because arc *AB* is known (it is 90º – the known arc *BG*), as in XXIII.4b ⟨13⟩. Then we have *BD*/*ḤB* = *ḤT*/*ZH* [= *BD/HD*, since *HD* = *ḤB*], also as in XXIII.4b ⟨13⟩.
[4] Its height is assumed to be 12 parts, i.e., digits (according to the definition in XXIII.2).
[5] *HD* (or *ḤB*) is not known as a magnitude, but—as it is approximately equal to the radius of the circumference—it is taken as the base circumference (on the basis of which the table is made), i.e., 60 parts; however, as *HB* = *HG*, its value is only approximate.
[6] Since *HṬ*/*ZH* = *BD*/*HD* then *ZH* = *HṬ*(*HD*/*BD*), where *HD*/*BD* (each term already known) is the cotangent of the angle of the altitude of the sun and is known, so that we can find the value of *ZH* (assuming, as previously said, that *HD* ∼ *ZD*).
[7] $\sin \alpha = \cos (90-\alpha)$. Given α as the angle of the altitude of the sun, the straight shadow is $12\cos \alpha/\sin \alpha$, and the inverted shadow is $12\sin \alpha/\cos \alpha$, as in Abraham bar Ḥiyya's *Sefer ḥešbon*, see Millás Vallicrosa 1959, 47–48 (Spanish), 41–42 (Hebrew), and nn. 74–75. But this statement repeats the previous proposition about finding the unknown shadow from the altitude. It should have said that since *BḤ* ~ *DZ* then *BD* = *BḤ*·*ṬH*/*ZH*.
[8] Abraham bar Ḥiyya uses this technical term (*meitar šeʾarit*) once in his *Sefer ḥešbon mahalekot ha-kokavim*; see Millás Vallicrosa 1959, 41 (Hebrew text).

<11> (63b) וזה להיות זוית א[1] [ז'][2] משותפת וזוית ד' נצבת שוה לזוית ה'. <12> {~~אם~~}[3] הנה א<ם> כ<ן> יחס ב'ד' שהוא מיתר מחוצה לגובה השמש הידוע מלוח הקשתות מצד כי {קשת}[4] ב'ד' ידוע אל קו ז'ד' השוה לקו ה'ד', <13> במציאות הידוע אחרי ששוה לקו ח'ב' הידוע {הידוע}[5] מצד היות קשתו ידועה כיחס העמוד שהוא ה'ט' הידוע שהוא י"ב אל צלו הנעלם שהוא ז'ה'. <14> ומפני שהתבאר בששי מאקלידס שד' שעורים מתיחסים שטח ה'א' ב'ד' בשטח ה'ב' ב'ג'. <15> הנה נכה קו ה'ט' שהוא העמוד הידוע בקו ה'ד' הידוע. <16> ונחלק העולה על קו ב'ד' הידוע ויצא קו ז'ה' הנעלם.

<.5> <1> ובזה הדרך יודע בכל עת [שיהיה][6] גובה השמש ידוע צל העמוד הישר לעת ההיא. <2> וזה שנכה מיתר מחוצה לשארית הגובה עם אורך העמוד, <3> ונחלק העולה על המיתר המחוצה לקשת הגובה ויצא הצל הנעלם.
<4> והנה יתבאר שבהיות גובה השמש מ"ה מעלות ישתוה הצל הישר עם אחר העמוד[7].
<5> וזה למה שהמיתר המחוצה לקשת הגובה שוה למיתר המחוצה מקשת שארית הגובה.

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[1] Crossed out (rightly).
[2] Interlineal correction, hand two.
[3] Crossed out (rightly).
[4] This is a mistake because 'ב'ד is not an arc, as the previous sentence makes clear.
[5] Hand five indicated it as wrong (rightly) with a dot on top of each of the three central characters.
[6] Interlineal addition, perhaps hand two.
[7] It should be העמוד האחר.

⟨6⟩ Therefore, when one multiplies the length of the gnomon by the sine of 45 degrees of the complementary altitude and divides it [the result] by the sine of the arc of altitude at that moment, which is 45 degrees, the result is the length of the ⟨straight⟩ shadow; or vice versa if it is the inverted shadow.[1]

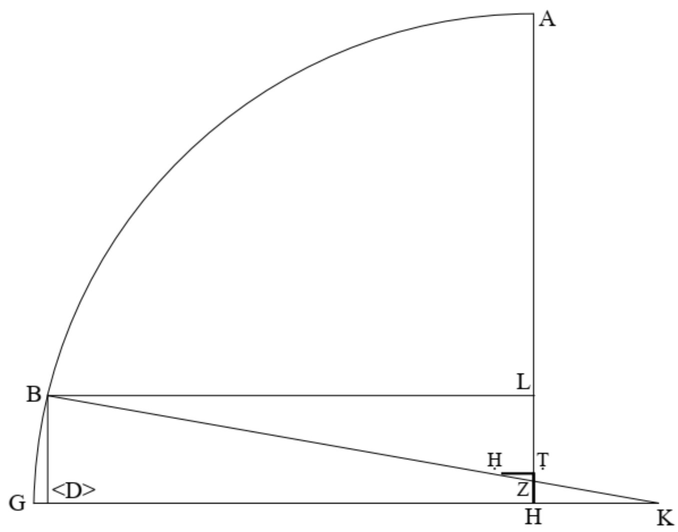

Diagram 2 (MS Paris BnF heb. 1030, f. 63b, on the lowest part of the right margin and within a space left blank by the scribe). The ray (*BZK*) of the rising sun is the projection from the tips of two gnomons: the vertical gnomon (*ZH*) projects shadow *HK* and the horizontal gnomon (*ṬḤ*) projects shadow *ṬZ*. H is the centre of the world and can be considered any location on the Earth given that this is so small in relation to the body of the sun that has no perceptible size. Letter *D* is not in the manuscript but has been added according to Diagram 1, where it is at the same position. The lines of the drawing in the manuscript are made with bright green ink and some of the letters with brown ink (*A*, *G*, *H*, *K* and *Ṭ*) and the remaining with bright red ink.

⟨XXIII.5a Example: Diagram 2⟩

⟨1⟩ Arc *ABG* corresponds to the quadrant of the altitude circle, the altitude of the sun is 10 degrees, which is arc *BG*. ⟨2⟩ [*HZ*][2] is the gnomon perpendicular to the plane of the horizon. ⟨3⟩ *ṬḤ* is the horizontal [*lit.* inverted] gnomon parallel to the plane of the horizon. ⟨4⟩ Line *ZḤB* is the ⟨solar⟩ ray. ⟨5⟩ *BD* is the sine (64a) of the arc of altitude. ⟨6⟩ *LB* is the sine ⟨of the arc⟩ of the complementary altitude. ⟨7⟩ Given the small size of the projections (מקישים) and their shadows, as well as their arcs and their chords, in relation to the sky, line *LZ* is considered approximately like line *LH*, which is equal to line *BD*. ⟨8⟩ As angle *L* is right, *Ṭ* is also right, and the angle at *Z* is common.

[1] The author means that both the tangent and cotangent of 45º are equal to the length of the gnomon.
[2] My correction of "*HṬ*," written in the manuscript. *HṬ* is effectively the gnomon, but any segment can work as a gnomon, so that *HZ*, which is a segment of the gnomon, can work as a gnomon.

<6> ולכן כשנכה אורך העמוד במיתר המחוצה למ"ה מעלות משארית הגובה, עוד נחלק אותו על מיתר המחוצה לקשת הגובה לעת ההיא שהוא מ"ה מעלות, יצא עוד אורך העמוד ונכח הענין בצל ההפוך.

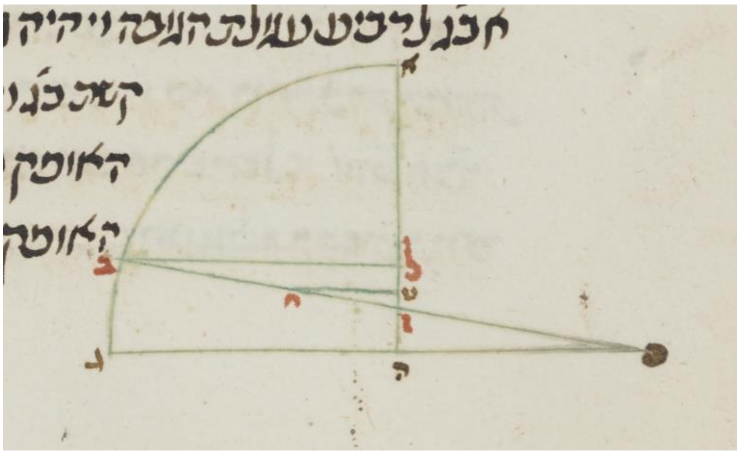

DIAGRAM 2: MS Paris BnF heb. 1030, f. 63b. Photo courtesy of the Bibliothèque nationale de France

<5א.> <1> ויהיה קשת א'ב'ג' לרביע עגולת הגובה ויהיה גובה השמש י' מעלות והיא קשת ב'ג', <2> וה'ט' העמוד הנצב על שטח האופק, <3> וט'ח' העמוד ההפוך נכחי לשטח האופק, <4> וקו ז'ח'ב' הנצוץ, <5> וב'ד' מיתר (64a) מחוצה {א}לקשת[1] הגובה, <6> ול'ב' מיתר מחוצה לשארית הגובה. <7> ומפני קוטן המקישים וצלליהם בערך אל השמים וקשתיהם ומיתרם הנה קו ל'ז' נחשב בקירוב כמו ל'ה'[2] קו השוה לקו ב'ד', <8> ומפני שזוית ל' נצבת וזוית ט' גם כן נצבת וזוית ז' משותפת.

[1] Hand six marked א as wrong.

[2] Hand seven marked this word with two dots and the following with one to indicate (rightly) an exchange in their order, so that one reads קו ל'ה' rather than ל'ה' קו

⟨XXIII.5b Demonstration of the example (Diagram 2)⟩

⟨1⟩ Triangles *ZṬḤ* and *ZLB* are similar. ⟨2⟩ For this reason the ratio of *ZL*, which is like *BD*, which is the sine of the arc of the solar altitude already known, to *LB*, which is the sine of the arc of the complementary altitude ⟨already⟩ known, is as the ratio of the inverted shadow [*ṬZ*] to the unknown, that is, *ṬZ* to the ⟨horizontal⟩ gnomon *ṬḤ*, ⟨already⟩ known.

⟨3⟩ For this reason we multiply the sine of the altitude [i.e., *BD*] by the ⟨horizontal⟩ gnomon *ṬḤ*, the value of which is always 12;[1] they both are the two extremes ⟨of the ratio⟩,[2] ⟨4⟩ and divide the result by the mean ⟨of the ratio⟩ that is known, which is *BL*, and the result is *ṬZ*, which is the value of the unknown inverted shadow. ⟨5⟩ Alternatively, we multiply the sine of the [altitude][3] [*BD*] by the length of the ⟨horizontal⟩ gnomon and divide the result by the sine of ⟨the complement of⟩ the altitude [*BL*]; the result is the value of the inverted shadow at that moment.[4] It is the same demonstration.

⟨XXIII.6 How one shadow is calculated from the other (Diagram 2)⟩

⟨1⟩ In order to realize how one knows one of the shadows from the other, let us assume that line *HZ* is on this diagram the straight [vertical] gnomon [*lit.* projection (המקיש)], for whichever the value it is always divided into 12 ⟨digits⟩. ⟨2⟩ The value of its shadow [of a gnomon] is in its divisions like the value [of <the> gnomon][5] in its divisions. ⟨3⟩ A ray *BZ* extends in a straight line until *K*, which is on the plane of the horizon. ⟨4⟩ *KH* is the straight shadow and *ṬZ* is the inverted one. ⟨5⟩ As opposite angles [*KZH*][6] ⟨and⟩ *ṬZḤ* are equal and the angles at *Ṭ* and at *H* are right, triangles *KZH* and *ṬZḤ* are similar. ⟨6⟩ Therefore, the ratio of *ṬḤ*, which is like the ⟨horizontal⟩ gnomon, to the inverted shadow, which is on *ṬZ*, is as the ratio of *KH*, which is the straight shadow, to *ZH*, which is the ⟨vertical⟩ gnomon.

⟨7⟩ If this is so, it is clear that if you know the inverted shadow and want to know the straight one from it, you multiply the gnomon *ṬḤ* by the gnomon *ZH*; (64b) they both are the extremes ⟨of the ratio⟩. ⟨8⟩ The value of each one [of the gnomons] is 12 and the product of both is 144. ⟨9⟩ Divide this ⟨number⟩ by the inverted shadow [*ṬZ*] and you get the straight shadow [*KH*]. ⟨10⟩ If you know the straight ⟨shadow⟩ and want to know the inverted one from it, divide 144 by the straight shadow and the result is the value of the inverted shadow.

[1] As regards this question, see Chapter XXIII.6 ⟨7⟩. Since both the gnomon and inverted gnomon are always 12, one would expect *ZH* and *ṬḤ* should be the same length (see Diagram 2). However, the diagrams in medieval texts rarely show equal lines as equal; see Saito and Sidoli 2012 (for Greek texts).

[2] *BD*/*BL* = *ṬZ*/*ṬḤ*.

[3] "Altitude" is my correction of "complementary altitude," written in the manuscript.

[4] Or we multiply the sine of the complementary altitude by the inverted shadow and divide by the sine of the altitude to give the (unknown) inverted gnomon.

[5] [Of <the> gnomon] is my correction of "of the shadow of a gnomon," written in the manuscript.

[6] [*KZH*] is my correction of "*KZḤ*," written in the manuscript.

<5ב.> <1> הנה משלשי ז'ט'ח' ז'ל'ב' מתדמים, <2> ולזה יחס ז'ל' השוה לב'ד' אשר הוא מיתר מחוצה לקשת גובה השמש הידוע[1] אל ל'ב' שהוא מיתר מחוצה לקשת שארית הגובה הידוע כיחס הצל ההפוך לנעלם שהוא ט'ז' אל העמוד שהוא ט"ח הידוע.
<3> ולזה נכה מיתר מחוצה לגובה בעמוד שהוא ט"ח ושעורו תמיד י"ב שהם שתי הקצוות, <4> ונחלק העולה על אחד האמצעי<ם> הידוע והוא ב'ל', ויצא ט"ז שהוא שעור הצל ההפוך הנעלם. <5> או נכה מיתר מחוצה לשארית הגובה באורך העמוד ונחלק העולה במיתר מחוצה לגובה, ויצא שעור הצל ההפוך לעת ההיא והמופת אחד.

<6.> <1> וכדי שנראה איך יודע אחד הצללי<ם> מהאחר, נניח בזאת התמונה קו ה'ז' המקיש הישר כי באי זה [שעור][2] שיונח תמיד יחלק על י"ב. <2> ויהיה שעור צלו מחלקיו כשעור {צל}[3] עמוד אחד מחלקיו. <3> ונוציא נצוץ ב'ז' הישר עד כ' שהוא בשטח האופק. <4> והנה כ'ה' הצל הישר וט'ז' ההפוך. <5> ומפני שזויות כ'ז'ח'[4] ט'ז'ח' המתנגדות שוות וזויות ט' ה' נצבות הנה משלשי כ'ז'ה' ט'ז'ח' מתדמים. <6> ולזה יחס ט'ח' מתדמים[5] העמוד אל הצל ההפוך שהוא בו[6] ט'ז' כיחס כ'ה' שהוא הצל הישר אל ז'ה' שהוא העמוד.
<7> ולזה אם כן מבואר שאם ידעת הצל ההפוך ותרצה לדעת ממנו הישר שתכה ט'ח' העמוד בז'ה' העמוד (64b) שהם הקצוות. <8> ושעור כל אחד י"ב והכאתם קמ"ד. <9> וחלק זה על הצל ההפוך ויצא לך הצל הישר. <10> ואם ידעת הישר ותרצה לדעת ממנו ההפוך חלק קמ"ד על הצל הישר ויצא שעור הצל ההפוך.

[1] ע written in superscript.
[2] Marginal addition, hand nine indicated its insertion with two dots written in the interlineal space above the line.
[3] This word must be a mistake and should be omitted (the comparison is between the value of the shadow and the value of the gnomon).
[4] It should be כ'ז'ה'.
[5] Hand six marked the word as wrong.
[6] This group of letters is not clear.

⟨XXIII.7 How to find the altitude using either of the two shadows (Diagram 2)⟩[1]

⟨1⟩ When you know all this, we need to explain how to find the altitude from either of the two shadows. ⟨2⟩ We come back to the previous diagram [Diagram 2]: line *KH* is the straight shadow ⟨already⟩ known. ⟨3⟩ As we already explained that triangle *KZH* is like a point ⟨by comparison to the actual size of the heavenly sphere⟩, then angle *ZKH* is as if it were on the centre of the world. ⟨4⟩ We already explained in the first section how to know line *KZ*,[2] which is opposite to the right ⟨angle⟩, if lines *KH* and *ZH*, already known of triangle *KZH*, form a right angle. ⟨5⟩ We add [*lit.* we take] the squares of lines *KH* and *HZ* and find the ⟨square⟩ root ⟨of their sum, which is the value of the unknown line *KZ*. ⟨6⟩ If you know the triangle, the angles of ⟨its⟩ lines are also known, because when we place line *BZ*—⟨equal to *BH* because triangle *KZH* is like a point⟩,[3] which is opposite to the right ⟨angle at *D* and is⟩ 60 part⟨s⟩,[4] we know by the same ratio we used in the first part, what ⟨shadow⟩ line *ZH*, which is the gnomon, casts. ⟨7⟩ Then we find its arc, that is, the [sine][5] of angle *ZKH*.[6]

⟨8⟩ The angle at the centre of the circle, which is the centre of the world, is known and the chord of the arc *BG* has as many divisions of the 360 ⟨degrees of the circle⟩ as *HKZ*, ⟨and the angles at⟩ *B* [*DBL*] ⟨and⟩ *D* [*BDH*] are ⟨both⟩ right ⟨angles⟩ of arc *BG*, which is the arc of the altitude of the 360 ⟨degree⟩ circle. ⟨9⟩ For this reason (אם כן), we always take the square of the shadow, which is the square of *HK*, and 144, which is always the square of the gnomon [*ZH*], add the two squares, and find its ⟨square⟩ root; this is the value of line *KZ*.

⟨10⟩ Then we say that the value of line *BZ* [= *BH* = 60 = the radius of the circle] is equal to the number of the divisions in the radius of the circle ⟨and⟩ line *ZH* has its 12 divisions.[7] ⟨11⟩ We multiply 12 by 60 [*BZ*] and divide the result by the value of line *KZ*; the result is the value of the line [*lit.* gnomon] [*BD*].[8] ⟨12⟩ This is also the method of ⟨Abraham bar Ḥiyya ha-⟩Nasi—of blessed memory—(65a) in the seventh chapter of his book *Calculation of the motions ⟨of the planets⟩*.[9]

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[1] A short clarification regarding the shadow square of an astrolabe that may help to understand Moses ben Abraham's explanation of the shadows from this section on. The straight shadow side (*umbra recta*) and the inverted shadow side (*umbra versa*) are set 12 digits out from the centre so that they form a square, 12 x 12, with markings for measurement only on the sides away from the vertical and horizontal diameters of the astrolabe. Thus there is a square, and if the ray is coming (normally) from the upper left quadrant, it passes through the centre of the astrolabe and crosses the shadow lines along either the bottom or the right-hand side of the square. One reads shadows cast from sunrise to 45º on the inverted shadow; from 45º to straight overhead (noon) on the straight shadow; from straight overhead/noon to 45º (as the sun sets) still on the straight shadow; and from 45º to sunset on the inverted shadow.

[2] See Chapter XXIII.4–4b. In this previous chapter there is no mention of how to determine *KZ*, although it is explained how to determine *KH* and *ZH*. The author shows how to determine *KZ* in Chapter XXIII.7 ⟨5⟩ using the Pythagorean theorem (and with examples in XXIII.7 ⟨6⟩–⟨12⟩).

[3] *BH* = *BK* because *K* and *H* are assumed to coincide.

[4] As *BH* is a radius of the circumference, its length is 60 parts.

[5] "Sine" is my correction of "chord," written in the manuscript.

[6] This means that instead of taking the arc, one takes the sine of the arc.

[7] Now he continues on the basis that the ratio of *BD* to *BZ* (which is also *BD* to *BH*) is as *ZH* to *ZK*.

[8] Line *BD* is the sine of the solar altitude and is not the gnomon.

[9] Cf. Millás Vallicrosa 1959, 41–42 (Hebrew text) and 47–48 (Spanish transl.).

<7.> <1> וכאשר ידעת כל זה הנה ראוי שנבאר איך [תדע][1] הגובה מן הצל איזה שיהיה. <2> ונשיב התמונה הקודמת[2] ויהיה קו כ'ה' הצל הישר הידוע. <3> ומפני שכבר אמרנו שמשלש כ'ז'ה' היא כדמיון נקודה הנה תהיה זוית ז'כ'ה' כאלו היא על מרכז העולם. <4> וכבר בארנו בחלק הא' שכאשר היו ידועים קוי כ'ה' ז'ה' ממשלש כ'ז'ה' נצב הזוית איך נדע קו כ'ז' שהוא כנגד הנצבה. <5> והוא שנקח מרובעי קוי כ'ה' ה'ז' ונוציא שרשם והוא יהיה שעור קו כ'ז' הנעלם. <6> וכאשר היה משלש ידוע הקוי<ם> הנה זויותיו ידועות, לזה כאשר נשים קו ב'ז' שכנגד הנצבה ס' חלק, נדע באותו היחס בדרך שקדם בחלק הא' כמה ישוב קו ז'ה' שהוא העמוד. <7> ונוציא קשתו והוא מיתר[3] לזוית ז'כ'ה'.

<8> וכאשר היתה זוית שעל מרכז העגול ידועה והיא על מרכז העולם ומיתר הקשת ב'ג' הנה כחלקים שהיא ה'כ'ז'[4] מש"ס ב'ד' נצבות תהיה קשת ב'ג' שהיא קשת הגובה מש"ס בעגול. <9> הנה אם כן תמיד אנו לוקחים מרובע הצל שהוא מרובע ה'כ' וקמ"ד שכן הוא תמיד מרובע העמוד ומחברי<ם> שני המרובעי<ם> ונוציא שרשם, והוא יהיה שעור קו כ'ז'.
<10> ואח<ר> כ<ך> אנו אומרי<ם> אם כשעור שקו ב'ז' הוא כך חלקים ישוב בחצי קטר עגולה קו ז'ה' שהוא י"ב חלקים כמה ישוב. <11> ונכה י"ב בס' ונחלק העולה על שעור קו כ'ז' ויצא שעור העמוד. <12> וזהו גם כן דרך הנשיא (65a) בשער ז' מספר חשבון המהלכות.

[1] Marginal addition, hand nine indicated its insertion with two dots written in the interlineal space above the line.
[2] ת written in superscript.
[3] It should be מיתר מחוצה.
[4] Hand seven wrote two dots between שהיא and ה'כ'ז', but there is no apparent mistake in them.

⟨XXIII.8 Calculating the altitude with the straight shadow ⟩

⟨1⟩ These are his [Bar Ḥiyya's] words: "If you know the shadow of the gnomon placed perpendicularly, which is called the extended [horizontal] shadow [*KH*], and you want to know the altitude corresponding to this shadow, you multiply the digits of this shadow by itself and add the result to 144, which is the square of the length of the gnomon. ⟨2⟩ Calculate the square root of the sum of these two squares; divide 720 by the square root you have found, the former being the result of multiplying the length of the gnomon [12] by the radius [60]. ⟨3⟩ The quotient of this division is its arc [of the altitude] and is the value of the altitude corresponding to the straight shadow," end of quote.[1] ⟨4⟩ You do for the inverted shadow what you did with the straight one; this is enough.

⟨XXIII.9 Calculating with shadows now using an astrolabe⟩

⟨1⟩ After knowing this, we come back to explain this question with the astrolabe. ⟨2⟩ We say that the shadow of any object when the sun is at 45 degrees of altitude is like its length. ⟨3⟩ For this reason, they engrave on the astrolabe the point at which the straight and the inverted shadows meet at 45 degrees in the quadrant of the circle of altitude that is the diametrical opposite to the quadrant in which altitudes are measured.

⟨XXIII.9a Description of the shadows engraved on the back of an astrolabe⟩

⟨1⟩ The line (העמוד) perpendicular to the plane of the horizon starts from the centre of the instrument and goes down to the angle of the earth. ⟨2⟩ The inverted line (העמוד) starts from the centre of the instrument and extends to the west. ⟨3⟩ These lines, ⟨which frame the shadow square⟩, do not have any graduation to calculate distance⟨s⟩. ⟨4⟩ It does not make any difference to measure an extension of land with the line going from east to west or with the one ⟨extending⟩ above it or below it. ⟨5⟩ As the alidade always crosses the⟨se⟩ two lines after they have intersected each other at the centre of the instrument, its crossing and falling on the ⟨straight or inverted⟩ shadow ⟨graduated line⟩s indicates the value of the ⟨corresponding⟩ shadows. ⟨6⟩ So that this happens, the shadow ⟨line⟩s must have been previously drawn in the quadrant that is diametrically opposite to the quadrant through which the solar ray ⟨starts⟩ to cross ⟨the instrument⟩. ⟨7⟩ Each line of the ⟨two⟩ shadows is divided into twelve equal parts [digits]; ⟨and the inverted shadow is used in the morning until the sun reaches 45 degrees⟩. ⟨8⟩ The straight shadow is ⟨used after the sun has reached an altitude of 45 degrees before midday and⟩ until the sun reaches ⟨again⟩ (65b) 45 degrees of altitude ⟨after midday when its straight shadow⟩ exceeds 12 digits;

[1] Millás Vallicrosa 1959, 41–42 (Hebrew text) and 47–48 (Spanish trans.). There is no mention of calculating the solar altitude with the shadow square in Abraham Ibn Ezra's *Sefer ha-middot*; see Lévy and Burnett 2006, 164–172 (measuring height).

<8.> <1> ז<ה> ל<שונו>: ואם תדע צל העמוד הנצב הנקרא צל נפרש ותהיה דורש לדעת גובה הראוי לצל ההוא אתה מרבע אצבעות הצל ההוא בעצמן והמרובע ההוא תהיה מוסיף עליו קמ"ד שהוא מר[ו]בע[1] אורך העמוד. <2> והנקבץ מב' המרובעים האלה הוצא את יסודו והיסוד העולה בידך חלק עליו תש"כ שהוא כפילת אורך העמוד במחצית הקטר. <3> והיוצא מחלוקה הוצא קשתו והוא ערך הגובה לצל ההוא הישר, ע<ד> כ<אן>. <4> ובדרך שעשית {בדרך}[2] בצל הישר כן תעשה בהפוך ודי בזה.

<9.> <1> ואחר שידעת זה נשוב לבאר זה הענין בכלי האצטרולב. <2> ונאמ<ר> כי למה שהיה צל כל דבר בהיות השמש במ"ה מעלות מגובהו הוא שוה לאורך עצמו. <3> לזה חוקקים הנקודה שיתחברו בה הצל הישר וההפוך בכלי האצטרולב {~~במ"ז~~}[3] על מ"ה מעלות מעגולת הגובה ברביע המקביל לרביע שבו ילקחו הגובהים.

<9א.> <1> ויהיה העמוד הנצב על שטח האופק הוא המתחיל ממרכז הכלי ויורד לצד יתד הארץ. <2> והעמוד ההפוך מתחיל ממרכז הכלי והולך לצד המערב, <3> ולהיות אלו הקוים אין להם שעור כערך אל הרוחק. <4> אין הבדל כשנדמה שטח הארץ הקו ההולך ממזרח למערב או למעלה ממנו או למטה. <5> ובעבור שהמעצר יעבור תמיד על שני העמודים אחרי שהם מתחברי<ם> במרכז הכלי, וכדמיון עברו ונפילתו על הצללים יהיה שעור הצללים. <6> לזה כבר היה מחוייב שיצויירו הצללי<ם> ברביע המקביל לרביע שנכנס בו נצוץ השמש. <7> ויחלקו כל קו מאלו הצללים לי"ב חלקים שוים. <8> והנה להיות הצל הישר עד היות השמש על (65b) מ"ה מעלות מגובהו גדול מי"ב אצבעות,

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[1] Interlineal addition, hand two.
[2] Hand six marked the word as wrong (rightly).
[3] Crossed out (rightly).

⟨9⟩ then ⟨we use⟩ the degrees of the inverted shadow [from][1] the moment the ⟨solar⟩ altitude is 45 degrees ⟨after midday until sunset⟩. ⟨10⟩ ⟨We use⟩ the straight shadow from 45 degrees upwards of ⟨solar⟩ altitude ⟨before midday⟩, for ⟨the shadow⟩ decreases progressively until midday.[2]

⟨XXIII.9b Finding the shadow of the altitude of the sun⟩[3]

⟨1⟩ When you have found the altitude of the sun and you want to know its shadow, if the altitude is less than 45 degrees, the alidade shall fall among the digits of the inverted shadow. ⟨2⟩ Observe how many digits there are between the point from which the alidade has fallen and the line going from the centre of the instrument to the west [the east-west line];[4] they are the digits of the inverted shadow. ⟨3⟩ If the altitude ⟨of the sun⟩ is more than 45 ⟨degrees⟩, the shadow shall fall among the digits of the straight ⟨shadow⟩. ⟨4⟩ Count how many digits there are between the lower meridian [*lit.* the angle of the earth] and the position where the alidade has fallen; they are the digits of the straight shadow for that moment.[5]

⟨XXIII.9c Finding the fractions of the digits of the shadow⟩

⟨1⟩ If the alidade falls between two digits and you want to know the fraction with accuracy, mark the position where the alidade has fallen on the altitude circle; this is the intermediate mark [*M3*]. ⟨2⟩ Place the alidade at the beginning of the digit and mark on the altitude scale [*lit.* circle] the position where ⟨the alidade⟩ has fallen; this is called the first mark [*M1*]. ⟨3⟩ Place again the alidade at the beginning of ⟨the next⟩ digit and mark the position on the altitude scale where ⟨the alidade⟩ has fallen; this is the last mark [*M2*]. ⟨4⟩ Find the ratio (ערך) of the degrees between the first and the intermediate marks [*M3*-*M1*] to the degrees between the first and the last marks [*M2*-*M1*]. ⟨5⟩ Multiply this ratio by 60 [*lit.* take this value in relation to sixty], which is the value of the fractions of one digit. ⟨6⟩ The result is exactly the fractions of the digit of the shadow. ⟨7⟩ If you want to know one of the shadows from the other, do as has been previously explained.[6]

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[1] "From" is my correction of "until," written in the manuscript.

[2] This sentence is superfluous since it repeats one of the situations previously noted in XXIII.9a, 8.

[3] Two calculations of this Chapter (XXIII.9b and XXIII.9d) are in two versions of Ibn Ezra's Hebrew treatises on the astrolabe; see MSS Paris BnF heb. 1053, ff. 13a–13b (the altitude with the shadow, first version), and Günzburg 937, ff. 7a–7b (the solar altitude with the shadow and the shadow with the solar altitude, third version).

[4] Since an astrolabe is engraved as if looking up into the sky, the west would be to the right (south being at the top).

[5] The line going down from the throne and across the centre on the back of the astrolabe works as the upper and the lower meridian lines given that the outer 360º scale (often a 90º scale in each quadrant) on the back of the astrolabe is used to measure altitude and so is an altitude scale. The same line works also as the line of the solstices, for in the calendar scales this line indicates upwards the summer solstice in the corresponding degree of the zodiac and the corresponding day of the corresponding month and downwards the winter solstice similarly.

[6] Chapter XXIII.6 (with a gnomon).

<9> לזה נשתמש עד היות גובה השמש מ"ה מעלות עם מעלות הצל ההפוך, <10> וממ"ה מעלות ולמעלה עם הצל הישר כי ילך ויקטן מאז עד חצות היום.

<9ב.> <1> והנה כאשר ידעת[1] גובה השמש ורצית לדעת ממנו הצל, אם הגובה פחות ממ"ה מעלות יפול המעצר על אצבעו<ת> הצל ההפוך. <2> וראה כמה אצבעות מן הנקודה שנפל ממנה המעצר עד הקו ההולך ממרכז הכלי למערב, והם אצבעות הצל ההפוך. <3> ואם הגובה יתר על מ"ה ונפל הצל על אצבעות הישר. <4> מנה מקו יתד הארץ עד מקום נפילת המעצר כמה אצבעות הם והם אצבעות הצל הישר לעת ההיא.

<9ג.> <1> ואם נפל הבריח על שברי אצבע ותרצה לדעת אמתת אלו השברים, רשום על מקום אשר נפל עליו הבריח בעגול הגובה סימן, והוא סימן אמצעי. <2> עוד שים הבריח על תחלת האצבע וסמן בעגול הגובה עם מקום נפילתו, ויקרא סימן ראשון. <3> עוד שים הבריח על תחלת האצבע ושים בעגול הגובה עם נפילתו סימן, ויקרא סימן אחרון. <4> ראה ערך המעלות שבין הסימן הראשון והאמצעי אל המעלות שבין הראשון והאחרון, <5> וכערך ההוא קח מס' שהוא שעור חלקי {ה}אצבע[2] <6> וההווה הם שברי אצבע הצל בדקדוק. <7> ואם תרצה לדעת אחד הצללים מהאחר עשה בדרך שקדם.

[1] All the script from the beginning of this folio until this word is written in larger size than the rest.
[2] Hand six marked ה as a mistake (rightly).

⟨XXIII.9d Finding the altitude of the sun using the shadow⟩

⟨1⟩ When you want to know the altitude of the sun from the shadow, if the shadow is inverted, place the alidade on the number ⟨you have⟩ of the digits of the inverted shadow. ⟨2⟩ If the shadow that you get is the straight, place the alidade on the number ⟨you have⟩ of the digits of the straight shadow. ⟨3⟩ The degrees of the altitude scale on which the end point of the alidade falls are the degrees of the altitude of the sun at that moment.

⟨XXIII.9e Finding the fractions of a digit of the altitude of the sun⟩

⟨1⟩ (66a) If you have fractions of a digit, find its ratio to 60 and place the end point of the alidade at the beginning of the digit. ⟨2⟩ Mark ⟨the position of⟩ the end point of the alidade on the altitude scale [*M1*]. ⟨3⟩ Place the alidade on the beginning of the ⟨next⟩ digit and mark ⟨the position of⟩ the end point on the altitude scale [*M2*]. ⟨4⟩ Observe ⟨how many⟩ degrees there are between the two marks [*M2*-*M1*] and apply to them the ratio of the fractions of digit with respect to 60. ⟨5⟩ Count th⟨is⟩ result, from the first mark [*M1*] to the second mark [*M2*], and place the end point of the alidade on the position where ⟨your⟩ counting ends. ⟨6⟩ The distance between the place where the ⟨end point of the⟩ alidade has fallen and the digit of the shadow is the value of ⟨the fraction of⟩ the digit equivalent to the minutes that you have.

⟨XXIV⟩ CHAPTER: TO CALCULATE THE AZIMUTH WITH THE SHADOW ⟨WITHOUT AN ASTROLABE⟩

⟨1⟩ Find the points of the east, the west, the north and the south in your location and extend from them two lines that intersect at right angles on the plane of the horizon.[1] ⟨2⟩ Place the centre on the place at which they intersect ⟨and draw a circle⟩. ⟨3⟩ Divide the circle into the 360 degrees of the sphere ⟨placing⟩ a gnomon [*lit.* needle] at a right angle ⟨in the centre⟩. ⟨4⟩ When you want to know the azimuth and the sun is in the east, observe on which of these [degrees][2] the [north-western][3] shadow falls. ⟨5⟩ Count how many degrees there are between the point of the west and the azimuth; this is the distance of the azimuth from the point east. ⟨6⟩ If it falls in the north-western quadrant, the azimuth is in the east-southern ⟨quadrant⟩ and its distance from the ⟨point of the⟩ east is the distance ⟨of the azimuth⟩ from the ⟨point of the⟩ west.

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[1] This is done according to the explanation in Chapter XXI.1–2b.
[2] “Degrees” is my correction of “lines,” written in the manuscript.
[3] “North-western” is my correction of “north-eastern,” written in the manuscript.

<9ד.> <1> וכאשר תרצה לדעת גובה השמש מפני הצל הנה אם היה הצל ההפוך שים המעצר על שעור אצבעות ההם מהצל ההפוך. <2> ואם הצל שבידך הוא הישר שים המעצר בשעור האצבעות ההם מהצל הישר. <3> {והאצבעות}[1] והמעלות שיפול עליהם קצה המעצר מעגולת הגובה הם מעלות גובה השמש לעת ההיא.

<9ה.> <1> (a66) והנה אם היו לך שברי אצבע דע ערכם אל ס' ושים קצה המעצר על תחלת האצבע, <2> וסמן סימן עם קצה המעצר בעגולת הגובה. <3> עוד שים המעצר על {קצה}[2] ראש האצבע וסמן עם קצה המעצר[3] בעגול הגובה, <4> וראה המעלות שבין שני הסימנין וקח מהמעלות כיחס שברי האצבע אל ס'. <5> ומנה כשעור[ם][4] מהסימן הראשון לצד הסימן השני ושים קצה המעצר במקום שיכלה החשבון. <6> ובמקום שיפול המעצר מאצבע הצל הוא שעור מאצבע כשעור הדקים שבידך.

<XXIV> **שער לדעת** הסימת בצל.

<1> תמצא בארצך נקודות מזרח ומערב צפון ודרום והוצא שני קוים מתחתכים על זויות נצבות בשטח האופק, <2> ובמקום שיתחתכו עשה מרכז <...>[5]. <3> וחלק העגולה לש"ס חלקים העגולה מחט על זוית נצבת. <4> וכאשר תרצה לדעת הסמת והשמש במזרח ראה על אי זה מהקוים[6] האלו יפול צל הצפוני המזרחי[7]. <5> מנה כמה מעלות מנקודת המערב עד הסמת וככה מספר מרחק הסמת מנקודת המזרח. <6> ואם נפל ברביע הצפוני מערבי הנה הסמת ברביע המזרחי הדרומי ומרחקו מהמזרח כמרחק ואחר מהמערב.

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[1] Hand six marked this word as a mistake (rightly).
[2] Hand six marked the word as wrong (rightly).
[3] צר written in superscript.
[4] Interlineal addition, hand two.
[5] A sentence is missing here. I have introduced it in the translation between ⟨ ⟩.
[6] It should be מהחלקים or מהמעלות.
[7] It should be הצפוני המערבי.

⟨XXV⟩ CHAPTER: TO KNOW THE TIME IF THERE IS NO PLATE FOR YOUR LATITUDE AMONG THE PLATES ⟨OF THE ASTROLABE⟩[1]

⟨1⟩ Take two latitudes among the ⟨latitude⟩ plates ⟨of your astrolabe⟩. ⟨2⟩ One of them must be ⟨for a latitude⟩ larger than the latitude of your location and the other ⟨for a latitude⟩ smaller than yours. ⟨3⟩ Find the difference between the latitude of your city and the latitude that is the closest to it. ⟨4⟩ Find its ratio [of the previous difference] with respect to the difference of the two latitudes that you have taken; keep this ratio. ⟨5⟩ Then you calculate with the two ⟨latitude⟩ plates the time for the same ⟨solar⟩ altitude that you took. ⟨6⟩ Find the difference between the two times (66b) of the two places and keep this difference. ⟨7⟩ Apply to this difference ⟨in time⟩ the ratio of the difference between the two latitudes that you kept. ⟨8⟩ Keep the hour and the fractions of hour that you get. ⟨9⟩ After that observe if the number of the hours of the closest latitude is less than the number ⟨of the hours⟩ of the other latitude; add these fractions of the hours to the number of the hours of the closest ⟨smaller⟩ latitude that have elapsed since midday; if it [the closest latitude] is larger, subtract it. ⟨10⟩ The result after adding or subtracting is the hours of the day that have elapsed ⟨since midday⟩ in your city using the altitude that you took.[2] ⟨11⟩ You shall do the same to know the hours of the night using the ⟨fixed⟩ stars and the azimuth of the sun by day and of the stars by night, and so on.

⟨XXVI⟩ CHAPTER: ON THE CALCULATION OF MORNING AND EVENING TWILIGHTS[3]

⟨1⟩ The ancients learnt by experience that the light of the sun is visible until the sun is 18 degrees of the altitude scale below the horizon in the evening. ⟨2⟩ When you want to know the evening twilight, which is the moment when darkness starts, place the degree diametrically opposite to the sun at 18 degrees of altitude among the eastern almucantars. ⟨3⟩ Observe on which of the divisions of the hours and fractions of the hour the degree of the sun falls. ⟨4⟩ It is the number of the hours of that night that have elapsed from the sunset to the occultation of its light. ⟨5⟩ Find the time of the night using the altitude of any ⟨fixed⟩ star as you did before and you shall know the time.

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[1] There is nothing about this calculation in Ibn Ezra's texts, but the procedure is very familiar employing two calculations and an interpolation between them, a method that Ibn Ezra presents as general (not in the specific context of this calculation) in the first Hebrew version of his astrolabe treatise; see MS Paris BnF heb. 1053, ff. 23a–23b.

[2] The tables display parameters for the meridian. At midday any two locations, whatever their latitude, if they have the same longitude, share the parameters at the meridian.

[3] This is a standard calculation and so it is found in Ibn Ezra's three Hebrew versions of his astrolabe text; see MSS Paris BnF heb. 1053, ff. 12a–12b (first version), BnF heb. 1045, f. 193a (second version), and Günzburg 937, f. 8b–9a (third version).

<XXV> **שער לדעת** השעה כאשר לא יהיה לוח ארצך אפק מזומן מתוך שאר הלוחות.

<1> קח מן הלוחות שני רחבים, <2> יהיה האחד מהם יותר גדול מרוחב ארצך והשני פחות ממנה. <3> וקח הבדל מה שבין רוחב עירך ורוחב היותר קרוב אליה. <4> ודע יחסו במה שבין השני רחבים אשר לקחת ושמור אותו היחס. <5> ואחר תדע עם כל אחד מהלוחות השעה לאותו הגובה שלקחת, <6> וראה ההפרש שבין שני השעות (66b) משני המקומות ושמור ההפרש ההוא. <7> קח מן ההפרש ההוא כיחס השמור אצלך אל השני מרחבים <8> ומה שיהיה משעה ושברי שעה שמרהו. <9> אח<ר> כ<ך> עיין אם מספר שעות הרחב היותר קרוב פחות ממספר הרוחב השני, תוסיף השברים ההם מן השעות על מספר שעות הרוחב הקרוב אשר עברו מחצי היום; ואם היה יותר תחסרהו. <10> ומה שיהיה אחר התוספת או הגרעון הוא מה שעבר משעות היום בעירך בגובה אשר לקחת. <11> וכן תעשה בידיעת שעות הלילה עם הככבים ובידיעת סמת השמש ביום והככבים בלילה וזולת זה.

<XXVI> **שער בידיעת** נשף היום ונשף הלילה.

<1> הנה הקודמים מצאו בנסיון כי אור השמש יראה עד היות השמש י"ח מעלות מעגול הגובה תחת האפק בערב. <2> וכאשר תרצה לדעת נשף הלילה והכוונה עת התחלת החשך שים המעלה הנכחית לשמש בגשרים המזרחיי<ם> בגובה י"ח מעלות, <3> וראה מעלת השמש על אי זה מהשעות וחלקי השעה יפול. <4> והוא יהיה שעור השעות שיעברו בלילה ההיא משקיעת השמש עד סור אורו. <5> דע השעה ההיא מהלילה מצד גובה ככב כמו שקדם ותמצא הרגע ההוא.

⟨6⟩ If you want the morning twilight, which is the moment when the light of the sun starts to spread in the atmosphere,[1] place the degree diametrically opposite to the sun on the altitude 18 degrees among the western almucantars. ⟨7⟩ Observe on which arc of the hours the degree of the sun has fallen, these are the hours that have elapsed from the night to the moment you are seeking.

⟨XXVII⟩ CHAPTER: TO FIND THE TWELVE ⟨ASTROLOGICAL⟩ HOUSES

⟨XXVII.1 The division of the four angles⟩

⟨1⟩ Know that the circle is always divided into four parts [quadrants] by two circles (67a), which are the circle of the horizon and the circle of the meridian. ⟨2⟩ For this reason the degrees of the zodiac at these four points are the cusps of the four houses that are called angles. ⟨3⟩ The first ⟨angle⟩ is the ascendant, which is the cusp of the first house. ⟨4⟩ The second is the angle of the earth, which is the cusp of the fourth house. ⟨5⟩ The third ⟨angle⟩ is the descendant, which is the cusp of the seventh house. ⟨6⟩ The fourth ⟨angle⟩ is the degree on the midheaven, which is the cusp of the tenth house. ⟨7⟩ We have ⟨already⟩ devoted a chapter above to their calculation.[2]

⟨XXVII.2 The division of the six astrological houses below the horizon using the seasonal hour divisions and a thread (the fixed rete method)⟩

⟨1⟩ The astrologers[3] divide what there is between each pair of these points [i.e., the angles] into three parts so that the circle is divided into 12 parts, six below the horizon and six above it; ⟨2⟩ this is the method to do it. ⟨3⟩ We take a thread, place ⟨it⟩ on the centre of the instrument, and make it cross the horizon at the point of the ascendant. ⟨4⟩ We make a mark ⟨on the position⟩ of the indicator [i.e., the beginning of Capricorn] and move ⟨the thread⟩ downward, that is, to the side of the angle of the earth until the indicator [i.e., the thread] falls far from the horizon on the ⟨horary⟩ arc that is the beginning of the eleventh hour.

[1] Moses ibn Abraham's description of the light in the twilights resounds with the anonymous Hebrew translator of MS Oxford Bodleian Libraries Opp. 697, f. 17a, who writes also in the 15th century but in an Ashkenazi context: "The degree of the sun when it reaches the circle of the twilight, which is 18 degrees before sunrise, is called the morning twilight. Then the sun is approaching the ⟨visible⟩ heavenly dome; ⟨as⟩ sunrise is ⟨becoming⟩ a little visible on the horizon, the night is not completely dark. In the same way, the light of sunrise [i.e., the light of the sun] in the ⟨heavenly⟩ dome disappears ⟨completely⟩ at night after sunset only after the degree of the sun reaches the circle of the twilight; this ⟨period between sunset and the circle of twilight⟩ is called the evening twilight."

[2] This question has been raised previously in Chapter V (the calculation of the ascendant or rising degree and the three remaining angles at one's latitude).

[3] The term *ha-'iṣṭagninim* is not frequent in astronomical texts; this is the first time that I have found it in an astrolabe treatise. Bar Ḥiyya uses this term (האצטגנינים), among other places, in his *Sefer ḥešbon*; see Millás Vallicrosa 1959, 52 (Spanish) and 46, line 13 (Hebrew), which Millás Vallicrosa translates as "astronomers" in the specific context of Bar Ḥiyya's passage. (In any case, the terms for "astronomers" and "astrologers," like their activities, overlap).

<6> ואם תרצה נשף היום והוא עת התחיל להתפשט אור השמש על האויר שים המעלה הנכחית לשמש בגשרים המערביים בגובה י"ח מעלות, <7> וראה מעלת השמש על אי זה מקשתי השעות נפלה והם השעות שיעברו מהלילה עד העת המבוקש.

<XXVII> שער להשוות[1] הי"ב בתים.

<1.> <1> דע כי תמיד יתחלק הגלגל על ד' חלקים עם שתי עגולות (67a) שהן[2] עגולת האופק ועגול חצי היום. <2> על כן יהיו המעלות מהמזלות שבאלו הד' נקודות התחלות[3] בתים[4] ארבעה[5] יקראו יתדות. <3> האחד הצומח והוא תחלת הבית הראשון, <4> השני יתד הארץ והוא תחלת הבית הרביעי, <5> הג' המעלה השוקעת והיא ראש הבית הז', <6> הד' המעלה שעם חצי השמים והוא התחלת[6] הבית הי'. <7> וכבר הפרדנו שער להוצאתם למעלה.

<2.> <1> ומה שבין כל שתי נקודות מאלו יחלקו האצטגנינים לג' חלקים באופן שיתחלק הגלגל לי"ב חלקים, ששה תחת האופק וששה ממעל לו, <2> וזה דרך הוצאתם. <3> נקח חוט ונשים במרכז הכלי ונשימהו עובר על האופק בנקודת המעלה הצומחת. <4> ונשים במורה סימן ונניעהו למטה רצו<ני> לצד קו יתד הארץ עד שיפול המורה רחוק מהאופק על הקשת שהוא התחלת[7] השעה הי"א.

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[1] The title of this chapter is not in bold script.
[2] ש is not clear because of the ink.
[3] It should be תחלות.
[4] It should be הבתים.
[5] It should be הארבעה.
[6] It should be תחלת.
[7] It should be תחלת.

⟨5⟩ We observe what degree of the zodiac ⟨in the rete⟩ the thread crosses; it indicates the cusp of the second house.[1]

⟨XXVII.3 The division of the six astrological houses below the horizon by the moving rete method⟩

⟨1⟩ To make the method easier, we place the rising degree on the angle of the earth and move the rete in the sense of the daily motion [rightwards] until the rising degree falls on the arc that is the beginning of the ninth hour. ⟨2⟩ The degree of the zodiac that is on the angle of the earth is the cusp of the second house. ⟨3⟩ Move the rete again until the rising degree falls on the ⟨horary⟩ arc that is the beginning of the eleventh hour. ⟨4⟩ The degree that is on the angle of the earth is the cusp of the third house. ⟨5⟩ Move again the rising degree to the line of the ⟨eastern⟩ horizon and the cusp of the fourth house shall return to the angle of the earth; ⟨6⟩ then the cusp of the seventh house is at the beginning of the western horizon. ⟨7⟩ Take this descending degree and move the rete until the setting degree ⟨falls⟩ on the [horary arc][2] of the beginning of the third hour. ⟨8⟩ The degree on the angle of the earth is the cusp of the fifth house. ⟨9⟩ Move the rete again until (67b) the setting degree falls on the ⟨horary⟩ arc that is the beginning of the fifth hour. ⟨10⟩ The degree on the angle of the earth is the cusp of the sixth house.

⟨XXVII.3a The division of the six astrological houses above the horizon⟩

⟨1⟩ When you find the six houses ⟨below the horizon⟩, you shall ⟨also⟩ know the six remaining ⟨houses⟩ that are above the horizon. ⟨2⟩ This is because the cusp of the first house is separated from the seventh by six zodiac signs. ⟨3⟩ And the same for the second house and the eighth, the third and the ninth, the fourth and the tenth, the fifth and the eleventh, and the sixth and the twelfth.

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[1] The thread is a tool to facilitate the reading of the hours on the zodiac scale of the rete aligned with some specific hour divisions. The method keeps the rete fixed and the intersections of the zodiac scale of the rete with the endlines of the even-numbered hour divisions (or the beginning of the uneven-numbered hour divisions) determine the cusps of the houses below the horizon. Each house above the horizon is determined with the diametrical opposite of the degree of the zodiac that is the cusp of the corresponding house below the horizon. The cusp of the fourth, tenth, first, and seventh houses are given by the degrees of the zodiac intersecting the lower and upper meridians and the eastern and western horizons, respectively. This method using the hour lines and a thread is the exact equivalent of the fixed rete method to calculate the houses; see, for example, Joseph ben Solomon Ṭaiṭaṣaq's explanation of this method in Rodríguez-Arribas and Kozodoy 2020, 92–93. Ibn Ezra does not use a thread but gives exactly the same method (the fixed rete method) in the Hebrew versions of his astrolabe text; see MSS Paris BnF heb. 1053, ff. 15b–16a (first version), BnF heb. 1045, f. 194a (second version), and Günzburg 937, f. (third version). Ibn Ezra clearly favored the fixed rete method (the only one he refers to), although he also refers in the first and second versions to a disagreement among the experts regarding the division of the houses that are not the angles; see ibid. Montalto, however, refers only to the moving rete method; see MS Paris BnF heb. 1047, f. 86a.

[2] "Horary arc" is my correction of "rete," written in the manuscript.

<5> ונראה החוט על אי זו מעלה יעבור מהמזלות והיא ראש הבית השני.

<.3> <1> ולהקל הדרך נשים המעלה הצומחת בקו יתד הארץ ונניע הרשת דרך תנועה[1] הכללית עד תפול למעלה הצומחת על קשת תחלת השעה התשיעית, <2> והמעלה מהמזלות שעם קו יתד הארץ היא ראש הבית השנית. <3> עוד הניע הרשת עד שתפול המעלה הצומחת על הקשת שהיא ראש[2] השעה הי"א, <4> והמעלה שעם יתד הארץ היא ראש הבית הג'. <5> עוד הניע המעלה הצומחת עד קו האופק וישוב עם קו יתד הארץ ראש הבית הד' <6> וראש הבית הז' בתחלת האופק המערבי. <7> קח זו המעלה השוקעת והניע הרשת עד תפול המעלה {~~הצומחת~~}[3] השוקעת על {הארץ}[4] הרשת[5] שהיא ראש השעה הג', <8> והמעלה שעם יתד הארץ היא ראש הבית הה'. <9> עוד הניע הרשת עד תפול (67b) המעלה השוקעת על הקשת שהיא ראש השעה הה', <10> והמעלה שעם יתד הארץ היא ראש הבית הששי.

<.3א> <1> וכאשר ידעת הששה בתים תדע הששה הנשארים אשר ממעל לאופק. <2> וזה שראש הבית הא' רחוק מהז' ו' מזלות <3> והבית השני מהשמיני והג' מהט' והד' מהי' והה' מהי"א והו' מהי"ב.

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[1] Hand seven marked it with two dots, possibly to indicate mistake. It should be התנועה.
[2] ש written in superscript.
[3] Crossed out (rightly).
[4] Hand six marked the word as wrong (rightly).
[5] It should be הקשת.

⟨XXVII.3b A simplified form to find the houses above the horizon by the moving rete method⟩

⟨1⟩ If you want ⟨to find⟩ this without calculation, know that when you place the rising degree on the angle of the earth, the descendant is on the midheaven. ⟨2⟩ And when the cusp of the second house is on the angle of the earth, observe the degree on the midheaven; it is the cusp of the eighth house. ⟨3⟩ When the cusp of the third house is on the angle of the earth, the [ninth house][1] shall be on the midheaven. ⟨4⟩ And so on with the remaining ones.

⟨XXVII.3c Demonstration of the moving rete method⟩

⟨1⟩ The reason for this is that the circle is always divided into 12 parts [houses], six of them toward the horizon's east and six of them toward the horizon's west. ⟨2⟩ The power of the eastern side changes into the power of the western side and the visible part in the east is the ascendant.[2]

⟨XXVII.3c Demonstration of the moving rete method⟩

⟨1⟩ The reason for this is that the circle is always divided into 12 parts [houses], six of them toward the horizon's east and six of them toward the horizon's west. ⟨2⟩ The power of the eastern side changes into the power of the western side and the visible part in the east is the ascendant. ⟨3⟩ For this reason the eastern houses are divided according to the value of the seasonal hours, two ⟨hours⟩ per house. ⟨4⟩ The same happens for the descendant, that is, the western side is divided according to the seasonal hours. ⟨5⟩ One needs to divide the eastern side below the horizon by the seasonal hours of the night and what is above the horizon by the diurnal ones, and the same for the western ⟨side⟩. ⟨6⟩ This is because of what has been described, that the rising degree produces one circle of those parallel to the equator.[3] ⟨7⟩ The part of this circle below the horizon is the nocturnal arc, while ⟨the part⟩ that is above the ascendant and above the horizon is the diurnal ⟨arc⟩. ⟨8⟩ You already know that the diurnal arc is divided into 12 seasonal hours so that from the ascendant (68a) to the meridian there are six seasonal hours. ⟨9⟩ As this quadrant is divided into three parts, each part has two seasonal diurnal hours. ⟨10⟩ For this reason, when we move the degree diametrically opposite to the ascendant two hours, the ⟨hours⟩ are diurnal with respect to the ascendant, just as when you calculated the time with the position of the sun. ⟨11⟩ The quadrant diametrically opposite to the quadrant between the ascendant and the midheaven is also divided into three parts, each one consisting of two seasonal [nocturnal][4] hours. ⟨12⟩ We divide the quadrant between the ascendant and the angle of the earth using the seasonal nocturnal hours, for we already moved the rising degree through the horary arcs that are nocturnal.

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[1] "Ninth house" is my correction of "descendant," written in the manuscript.
[2] For the concept of "power" (*koaḥ*) and its relevance in medieval astral sciences, see Rodríguez-Arribas 2015. I assume that the presence of this term in Moses ibn Abraham's treatise on the astrolabe means that he was familiar with astrological works in which this term was used, perhaps those of Ibn Ezra. The term, with an astrological meaning, is not found in Abraham Ibn Ezra's treatises on the astrolabe.
[3] See Chapter IV.4a.
[4] "Nocturnal" is my correction of "diurnal," written in the manuscript.

<3ב.> <1> והנה אם רצית זה מבלי חשבון דע כי כאשר שמת המעלה הצומחת בקו יתד הארץ תהיה השוקעת עם קו חצי השמים. <2> וכאשר באה תחלת הבית הב' בקו יתד הארץ תסתכל אל המעלה שעם קו חצי השמים והיא ראש הבית הח'. <3> וכאשר היתה תחלת הבית הג' בקו יתד[1] הארץ תהיה השוקעת[2] עם קו חצי השמים, <4> {~~וכאשר~~}[3] וכן כל השאר.

<3ג.> <1> וסבת זה כי הגלגל יחלקו תמיד על י"ב חלקים ששה מהם בצד המזרחי מהאופק וששה מהם בצד המערבי מהאופק, <2> ולהיות שכח הצד המזרחי יתחלף לכח הצד המערבי והחלק הוראה שבמזרחי המעלה הצומחת. <3> על כן יחלקו הבתים המזרחיים לפי שעור שעותיו המעוותות, שתים מהם לכל בית. <4> וכן הענין במעלה {הצומחת}[4] השוקעת רצ<וני> שעם שעותיה המעוותות[5] נחלק הצד המערבי. <5> והנה צריך לחלק הצד המזרחי שתחת לאופק {ש}עם[6] השעות המעוותות הליליות ושממעל לאופק עם היומיות וכן המערבי. <6> והנה יהיה זה עם זה המעשה בזה התאר כי הנה המעלה הצומחת תחדש עגולה אחת מהנכחיות למשוה, <7> ואשר ממנה תחת האופק היא הקשת הלילית למעלה הצומחת ההיא ושלמעלה מהאופק היומית. <8> וכבר ידעת כי הקשת היומית תתחלק על י"ב שעות מעוותות באופן שמה שמהצומחת (68a) עד חצי השמים הם ו' שעות מעוותות, <9> ומפני כי זה הרביעי יחלק לג' חלקים הנה יגיע לכל חלק ב' שעות מעוותות יומיות. <10> ולזה בנהגנו עם המעלה הנכחית לצומחת שתי שעות הם יומיות לצומחת בדרך שקדם בהוצאת השעה מפני מקום השמש, <11> הרביע ההוא הנכחי לרביע שמהצומחת עד חצי השמים לשלשה חלקים כל חלק מב' שעות מעוות[7] יומי[ו]ת[8] יחלק הוא לחלקים אלו. <12> והרביע ש{~~ה~~}מהצומחת[9] עד יתד הארץ חלקנוהו עם השעות המעוותות[10] הליליות כי כבר נהגנו המעלה הצומחת עצמה על קשתי השעות והם ליליות.

[1] Hand seven marked the word with two dots, the word is not a mistake.
[2] It should be 'הבית הט.
[3] Crossed out (rightly).
[4] Hand six marked the word as wrong (rightly).
[5] ת written in superscript.
[6] Hand six marked the letter as a mistake (rightly).
[7] It should be מעוותות.
[8] Interlineal addition, hand two. It should be ליליות.
[9] The second letter of the group seems to be crossed out (rightly).
[10] תות written in superscript.

⟨13⟩ Just like the expert understands what has been said above, it is ⟨also⟩ clear for those who understand the craft that the diurnal seasonal hours are related to the ascendant as the nocturnal ones are to the [descendant],[1] and the nocturnal ones ⟨are related to the descendant⟩ as the diurnal ones to the ascendant.[2] ⟨14⟩ For this reason, according to what has been said above, the division of the houses is correct according to the requirement of the art, i.e., the art of ⟨the astrological⟩ judgement⟨s⟩.

⟨XXVIII⟩ CHAPTER: TO KNOW THE MEASURE OF WHICHEVER OF THE THREE DIMENSIONS[3]

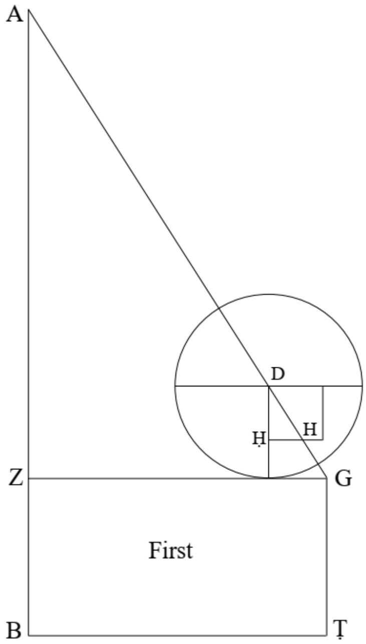

Diagram 3 (MS Paris BnF heb. 1030, f. 68a, on the lower half of the right margin and indenting into the text). An outline of the shadow square of an astrolabe and the angle of the visual ray of the agent when he is calculating the height of an object (*BA*) and the alidade falls on the side of the straight shadow of the shadow square. *GṬ* is the stature of the person (from feet to eyes) who is measuring the object with the astrolabe. The drawing in the manuscript was made with the lines in bright red ink, letters with green ink, and the perimeter of the small circumference that represents the astrolabe with brown ink. The original drawing shows the shadow falling on the straight shadow, which rightly corresponds to the description in the text.

[1] "Descendant" is my correction of "ascendant," written in the manuscript.
[2] This explanation means that the diurnal hours start and progress from the ascendant just as the nocturnal ones start from the descendant and that each diurnal hour is diametrically opposite to the corresponding nocturnal hour and vice versa.
[3] Instructions to measure the height and depth of objects and the distance between two points are given in Ibn Ezra's three Hebrew treatises on the astrolabe, but none of them uses diagrams or examples; see MSS Paris BnF heb. 1053, f. 33a–34a (first version), BnF heb. 1045, f. 188a (second version, briefly mention of the calculation without instructions), and Günzburg 937, f. 12b–13b (third version).

<13> אז, כמו שיתבאר למבין מה שקדם והוא מבואר למביני במלאכה שהשעות המעוותות היומיות לנכחית לצומחת[1] כמו הליליות לצומחת והליליות כמו היומיות לצומחת. <14> לכן הנה יצא עם מה שקדם חלוק הבתים על נכון כפי צורך המלאכה רצו<ני> מלאכת המשפט.

<XXVIII> שער לדעת מדידת[2] שעור אי זה שנרצה מהמרחקי<ם> הג'.

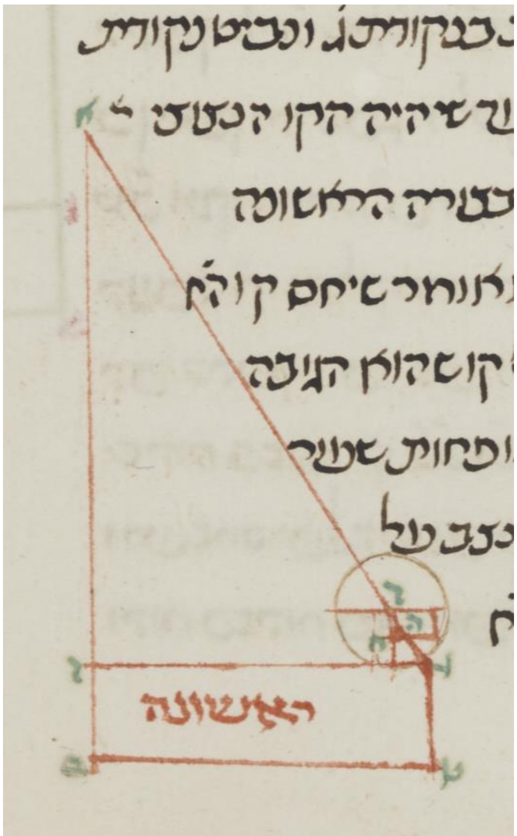

DIAGRAM 3: MS Paris BnF heb. 1030, f. 68a. Photo courtesy of the Bibliothèque nationale de France

[1] It should be לשוקעת.
[2] The title of this chapter is not in bold script.

⟨XXVIII.1 Measuring the height with the shadow square (Diagram 3)⟩

⟨1⟩ First of all we consider the height *AB*, whose measure we want to know. ⟨2⟩ The visual ray is at point *G* and we look at point *A* ⟨through the alidade⟩ of the astrolabe, in the same way that we observe the altitude of any star, ⟨3⟩ until the ray of light through the sighting holes of the astrolabe—line *GDA*[1]—falls in the first diagram [i.e., Diagram 3 here] on the straight shadow and delimits on it the length of line *HḤ*. ⟨4⟩ I say that the ratio of line *HḤ* to 12 is as the ratio of the distance between you and the base of the high object [*GZ* or *TB*] to the line of the height [*AZ*]. ⟨5⟩ Always know that when we say the height, we mean ⟨the height of the object⟩ [*AB*] minus the value of the stature [*ZB*];[2] ⟨6⟩ the proof is that *DḤ*, perpendicular to the plane of the horizon, is parallel to line *AB*. ⟨7⟩ Angle *HDḤ* (68b), which is exterior, is equal to angle *HAZ*, which is interior ⟨and⟩ opposite to it,[3] according to ⟨Proposition⟩ 29, Book 1 of Euclid.[4] ⟨8⟩ Line *GZ* goes out from the eye ⟨to the object⟩; ⟨9⟩ the angle⟨s⟩ at *Z* and at *Ḥ* are right and, according to ⟨Proposition⟩ 4, ⟨Book 6⟩ of Euclid, triangles *AGZ* and *HDḤ* are similar.[5] ⟨10⟩ The ratio of *HḤ* to *ḤD*, which is 12 digits, is as the ratio of *GZ* to *AZ*. ⟨11⟩ For this reason we measure ⟨the distance⟩ between us and the high object, because line *GZ* is like *ṬB*, and we keep the result. ⟨12⟩ We shall find the ratio of line *HḤ* to 12 ⟨with the instrument⟩, and the ratio between the cubits of line *ṬB* and line *AZ* is as this ratio. ⟨13⟩ We multiply the cubits of line *GZ* by ⟨the reciprocal of⟩ this ratio and the result is the cubits of line *AZ*.[6] ⟨14⟩ Alternatively, we divide the cubits of line *GZ* by the digits of line *HḤ* and multiply the quotient of the⟨ir⟩ division by 12; ⟨15⟩ the product is the cubits of line *AZ*.[7] ⟨16⟩ Alternatively, we multiply *GZ* by 12 ⟨digits⟩—the mean ⟨of the ratio⟩— and divide the result by *HḤ*; the result is line *AZ*.[8] ⟨17⟩ We measure the value of our stature, that is, the number of cubits between the eyes and the ground, which is line *GṬ*, which is equal to *BZ*, and add these cubits to the cubits of line *AZ*. ⟨18⟩ The result is the total of the cubits of the height ⟨of the object⟩ with accuracy.

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[1] The order of the letters should be *ADG*, which is the direction of the ray.

[2] As Moses ben Abraham explains later (XXVIII.1, 17), "stature" means actually "the number of cubits between the eyes and the ground."

[3] They are two equal angles of two similar triangles.

[4] Heath 1926, 1:311: "A straight line falling on parallel straight lines makes the alternate angles equal to one another, the exterior angle equal to the interior and opposite angle, and the interior angles on the same side equal to two right angles."

[5] Heath 1926, 2:200: "In equiangular triangles the sides about the equal angles are proportional, and those are corresponding sides which subtend the equal angles."

[6] *GZ* × (12/*HḤ*) = *AZ*.

[7] (*GZ*/*HḤ*) × 12 = *AZ*.

[8] It is highly significant of the possible teaching context of Moses ben Abraham's text on the astrolabe that he repeats the same thing (*GZ*/*HḤ* × 12) three times in three different ways (XXVIII.1, 13–16), just ordering the elements and functions differently.

<1.> <1> ונשים תחלה גובה א'ב' שנרצה לדעת שעורו. <2> ויהיה נצוץ הראות בנקודת ג' ונביט נקודת א' באצטרולב כדרך שנביט גובה ככב <3> עד שיהיה הקו הנצוצי הנכנס בנקבי האצטרולב קו ג'ד'א' ויפול בצורה הראשונה על הצל הישר, ויבדיל ממנו שעור קו ה'ח'. <4> ואומר שיחס קו ה'ח' אל י"ב כיחס המרחק שבינך ושרש הגובה אל קו שהוא הגובה. <5> וכן דע תמיד כי כשנאמ<ר> הגובה נרצה בו פחות שעור הקומה, <6> המופת מפני שד'ח' נצב על שלוח האופק נכחי לקו א"ב. <7> הנה זוית ה'ד'ח' (68b) החיצונה שוה לזוית ה'א'ז' הפנימית הנגדית אליה מכ<">ט מ<אמר> א' מאיק<לידס>. <8> ונוציא מהעין קו ג'ז'; <9> הנה זוית ז' וח' נצבות לזו מד' כמו באיק<לידס> משלשי א'ג'ז' ה'ד'ח' מתדמים. <10> הנה יחס ה'ח' אל ח'ד' שהוא י"ב אצבעו<ת> כיחס ג'ז' אל א'ז'. <11> ולזה נמדוד מה שבינינו לגובה כי קו ג'ז' כמו ט'ב' ונשמרהו. <12> ונדע קו ה'ח' מה יחסו אל י"ב וכיחס ההוא הוא יחס האמות שיש בקו ט'ב' אל האמות שיש בקו א'ז'. <13> ונכה האמות שבקו ג'ז' ביחס ההוא ויצאו האמות שיש בקו א'ז'; <14> או נחלק אמות קו ג'ז' על אצבעות קו ה'ח' והיוצא בחלוק נכהו עם י"ב <15> ויצאו האמות שבקו א'ז', <16> או נכה ג'ז' בי"ב האמצעיים והעולה נחלק על ה'ח' ויצא קו א'ז'. <17> נמדוד שעור קומתנו רצו<ני> מה שמהראות עד הארץ שהוא קו ג'ט' השוה לב'ז' כמה מהאמות יש ונוסיפם על אמות קו א'ז', <18> ויצאו כל אמות גובה בדקדוק.

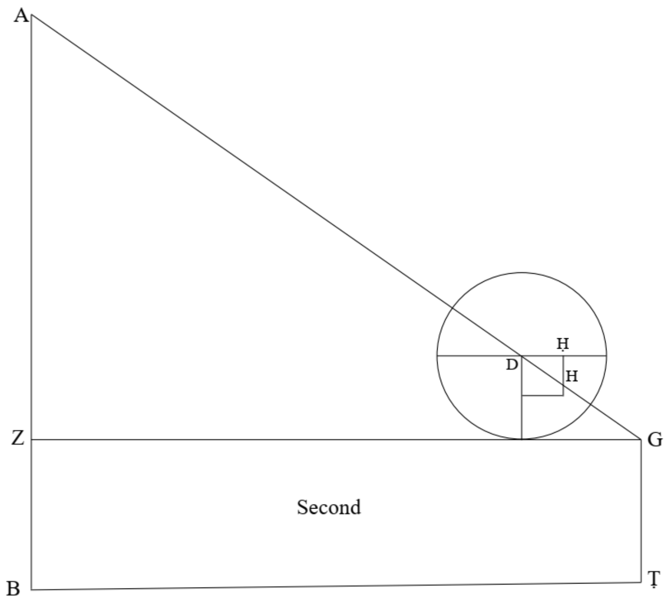

Diagram 4a (MS Paris BnF heb. 1030, f. 68b, on the lower half of the right margin). An outline of the shadow square of an astrolabe and the visual ray of the agent when he is calculating the height of an object (*BA*) and the alidade falls on the side of the inverted shadow on the shadow square. *GṬ* is the stature of the person who is measuring the object with an astrolabe. The drawing in the manuscript shows the lines in green ink, letters in red (with an alternation of green-red-green-red in the word שנית, "second", at the lowest part of the image), and the perimeter of the circumference of the astrolabe in brown ink. The original image shows the shadow falling on the side of the inverted shadow, which agrees with the description in the text.

⟨XXVIII.2 Calculating the height with the inverted shadow (Diagram 4a)⟩

⟨1⟩ On the second diagram [Diagram 4a] the ray falls on the inverted shadow. ⟨2⟩ Triangles *HḤD* and *AZG* are similar, for line⟨s⟩ *ḤH* and *AZ* are parallel. ⟨3⟩ Angles *AHḤ*[1] and *ZAH*, which are alternate [*lit.* exchanged], are equal and the angles at *Ḥ* and *Z* are right. ⟨4⟩ Because of this, the ratio of *ḤH*, which are the digits of the inverted shadow, to *ḤD*, which is 12 digits, is as the ratio of *AZ* to *GZ*, which is the distance between the eye and the observed thing.[2] ⟨5⟩ For this reason, we count the number of the cubits on line *GZ*, which is equal to line *ṬB* and take from it as much as [i.e., multiply it by] the ratio of the inverted shadow to 12; ⟨6⟩ the result is the ⟨number of⟩ cubits of the height [*AZ*]. ⟨7⟩ Alternatively, we divide the cubits of line *GZ* by 12 and multiply the quotient by the digits of the inverted shadow [*HḤ*]; ⟨8⟩ the result is the value of line *AZ*. ⟨9⟩ We add to this the cubits of the stature, which is the value of line *ZB*; ⟨10⟩ the result is all the cubits of the height with accuracy.

[1] It would be more correct if this angle were defined as "*DHḤ*," but there is no mistake in Moses' text.
[2] *ḤH*/*ḤD* = *AZ*/*GZ*.

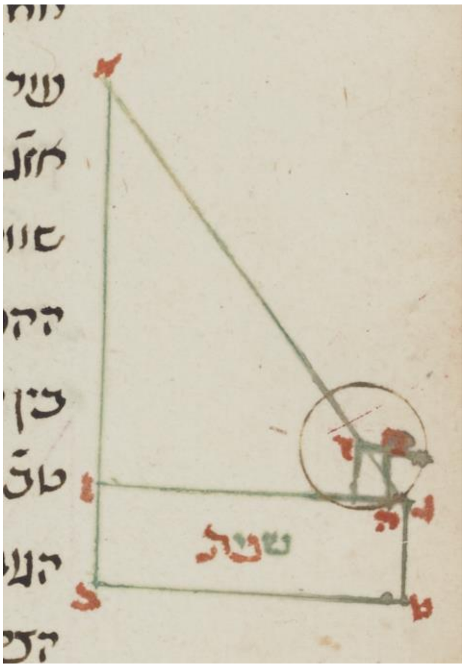

DIAGRAM 4: MS Paris BnF heb. 1030, f. 68b. Photo courtesy of the Bibliothèque nationale de France

<2.> <1> עוד יפול בצורה השנית הנצוץ על הצל ההפוך. <2> והנה משלשי ה'ח'ד' א'ז'ג' מתדמים כי קו ח'ה' א'ז' נכחיים. <3> הנה זויות א'ה'ח' ז'א'ה' המומרות[1] שוות וזויות ח' ז' נצבות שוות. <4> ולזה יחס ח'ה' שהם אצבעות הצל ההפוך אל ח'ד' שהוא י"ב אצבעות כיחס א'ז' אל ג'ז' שהוא המרחק בין העין והמובט. <5> ולכן נמנה כמה אמות יש בקו ג'ז' השוה לקו ט'ב' ונקח ממנו כיחס[2] הצל ההפוך אל י"ב; <6> והעולה יהיו שעור אמות הגובה, <7> או נחלק אמות קו ג'ז' על י"ב והיוצא נכהו עם אצבעות הצל ההפוך, <8> ויצא שעור קו א'ז'. <9> נצרף לזה אמות גובה הקומה שהוא בשעור קו {~~דב~~}[3] ז'ב', <10> ויצאו כל אמות הגובה בדקדוק.

[1] ת written in superscript.
[2] Written ביחס.
[3] Crossed out (rightly). The first letter is not clearly legible.

⟨XXVIII.3 Calculating the height when the angle is 45 degrees⟩[1]

⟨1⟩ Know that if the alidade falls on the point that the straight and the inverted shadows share, which happens when the height ⟨falls⟩ on 45 degrees, (69a) the distance between you and ⟨the basis of⟩ the object adding the value of your stature is the height of the object. ⟨2⟩ So if you place the alidade at 45 degrees of altitude, get nearer or farther with respect to the height until seeing its top through the sighting holes of the alidade. ⟨3⟩ Keep it in its place—I mean, the alidade—for the distance between you and the basis of the object adding your stature is the height of the object.

⟨XXVIII.4 What to do when the base of the height is not accessible for the observation⟩

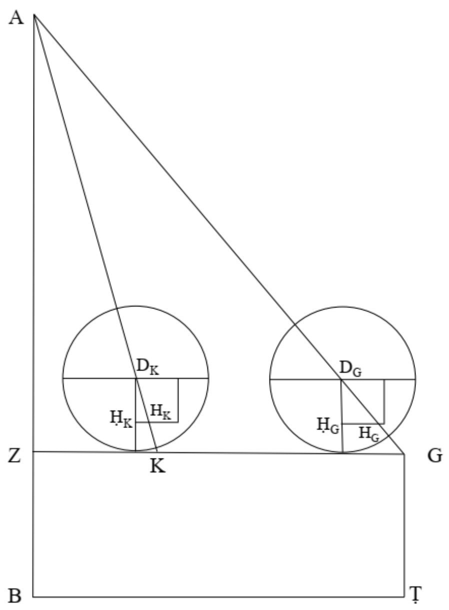

Diagram 4b (not in the MS). An outline of the shadow square of an astrolabe and the visual ray of the agent when he is calculating the height of an object (*BA*) and the base of the object is not accessible for the observation (the agent cannot measure *BṬ*). Then he measures from two different positions (*K* and *G*) whose separation can be measured and he calculates the height relating the distances between the two points of observation and the different values of the measured angles (reflected by the number of the digits of the corresponding shadow). Diagram 4b is not in the MS and I have included it to clarify the specific calculation that Moses ben Abraham is explaining.

⟨1⟩ If you want to measure a high object, ⟨but⟩ you cannot reach its base because of some obstacle like a mountain or because ⟨the object⟩ is placed in the middle of water, you proceed as follows.

[1] The calculation of the height of an object using the shadow square in different circumstances (XXVIII.3-XXVIII.4) is also found in two of Ibn Ezra's Hebrew versions of his astrolabe text; see MSS Paris BnF heb. 1053, ff. 21b–22b (first version) and Günzburg 937, ff. 12b–13b (third version). There are neither examples nor diagrams in Ibn Ezra's texts.

<.3> <1> ודע שאם יפול המעצר על הנקודה המשותפת לצל הישר וההפוך והוא כשהוא במ"ה מעלות מהגובה {~~והתקרבת והתרחקת~~}[1] הנה (69a) מה שבינך לדבר עם תוספת שעור קומתך הוא כמו גובה הדבר. <2> ומזה אם כן שאם שמת המעצר על מ"ה מעלות מהגובה והתקרבת והתרחקת לגובה עד ראית ראשו מנקבי המעצר, <3> והוא קיים על מקומו רצו<ני> המעצר שהנה מה שבינך לשרש הדבר עם תוספת קומתך הוא גובה הדבר.

<.4> <1> אם רצית מדידת דבר גבוה אין אתה יכול להגיע אל שרשה מפני מונע כגון הר או הוא במים תעשה כן.

[1] Crossed out (rightly). It looks as if someone had partially effaced the two words and only the upper part of the letters remain.

⟨2⟩ Observe the top of the object from a position that is called the first position [*K*]. ⟨3⟩ You observe on which digits and shadow the alidade has fallen. ⟨4⟩ If it falls on the straight ⟨shadow⟩, the ratio of the digits of the straight shadow to 12 is as the ratio of the distance between you and the base of the object to its height; keep this ratio. ⟨5⟩ If ⟨the alidade⟩ falls on the inverted shadow, the ratio of the inverted shadow to 12 is as the ratio of the height to the distance between you and the base; keep it. ⟨6⟩ After that, you get nearer or farther ⟨in a straight line⟩ from the object toward a second position [*G*] and observe from it the top of the object a second time. ⟨7⟩ Observe if the alidade has fallen on the straight or on the inverted ⟨shadow⟩ and consider the ratio as you did before.
⟨8⟩ Given the difficulty of th⟨is⟩ calculation, we give an example so that it is understood. ⟨9⟩ In the two observations, the alidade [when at position *K*] fell first on the straight shadow and the ratio of the distance between us and the base to the object was as the ratio of 8 to 12. ⟨10⟩ When we got farther [from the object, i.e., when at position *G*], the ratio of the distance between us and the base of the height was as the ratio of 10 to 12. ⟨11⟩ We have calculated the difference between the two ratios and it is one sixth. ⟨12⟩ We measured the distance between the ⟨two⟩ positions, that is, the first and the second ⟨positions⟩ on which we stood, and it was 10 cubits. ⟨13⟩ The distance between the first position and the base is 4/6 of the height and the distance between the second position and the base is 5/6 of the height. ⟨14⟩ As the difference between them is 1/6 of the height, we measured this sixth and it was 10 cubits. ⟨15⟩ When one multiplies it by 6, the product is the value of the height.[1] ⟨16⟩ One has added the value of the stature ⟨to this product⟩ and the result is the complete height ⟨of the object⟩.
⟨17⟩ If the alidade falls (69b) both times on the inverted shadow, the height is 4/6 ⟨of the distance from the first (and furthest) position *G* to the object⟩. ⟨18⟩ For this reason, the distance between the first position [*G*] and the base is as the height and its half. ⟨19⟩ When we go nearer [to the object], the height was 5/6 of the distance between the second position [*K*] and the base ⟨of the object⟩, so it [the distance between the second position and the base] is as the height and 1/5 of it [the height]. ⟨20⟩ We subtract 1/5 from the half ⟨of the height⟩ to find that the difference between the largest and the smallest distances from the base is as 1/2 of the height minus 1/5 of it [the height]. ⟨21⟩ The remainder is 1/5 and 1/2 and this 1/5 and 1/2[2] is the distance that we measured between the two positions and was 10 cubits.

[1] The distance between the first and the second positions is 10 cubits. The formula can be expressed as in XVIII.1, ⟨10⟩: $(H_G Ḥ / HD)AZ - (H_K Ḥ / HD)AZ = (10/12)AZ - (8/12)AZ = (5/6)AZ - (4/6)AZ = (1/6)AZ = 10$ cubits. If we multiply by 6, then $AZ = 10 \times 6 = 60$ cubits.
[2] "1/5 and 1/2" does not mean that 1/5 is added to 1/2, rather it is (1/2−1/5); they are separated numbers that Moses is going to use in the next sentence (XXVII.4, 22).

<2> תביט קצה הדבר ממקום מה ויקרא מקום ראשון <3> ותראה הבריח על כמה אצבעות נפל מאחד הצללים. <4> ואם נפל על הישר הנה כיחס אצבעות הצל הישר אל י"ב כן יחס מה שבינך ובין שורש הדבר אל גובהו; שמור היחס ההוא. <5> ואם נפל על הצל ההפוך הנה כיחס הצל ההפוך אל י"ב כן יחס הגובה אל מה שבינך והשרש;[1] שמור אותו. <6> אח<ר> כ<ך> תקרב או תרחק מהדבר אל מקום שני ותביט ממנו עוד ראש הדבר. <7> וראה אם נפל המעצר בישר או בהפוך וראה היחס כמו שקדם.

<8> ונניח משל לקושי הענין כדי שיובן. <9> ויהיה תחלה שנפל המעצר בשתי ההבטות על הצל הישר והיה היחס שממה שבינינו והשרש אל הדבר כיחס ח' אל י"ב. <10> וכאשר נתרחקנו היה יחס מה שבינינו והשרש[2] והגובה[3] כיחס י' אל י"ב. <11> לקחנו יתרון מה שבין היחסי<ם> והוא ששית אחת. <12> ומדדנו מה שבין המקומות רצו<ני> הראשון והשני שעמדנו בהם והיו י' אמות. <13> והנה מה שבין המקום הראשון והשרש הוא ד' ששיות הגובה ומה שבין המקום השני והשרש הוא ה' ששיות מן הגובה. <14> ומפני שתוספת האחד על האחר הוא ששית מהגובה ומדדנו זה הששית והיה י' אמות. <15> הנה כשיכפל זה בששה יהיה העולה שעור הגובה, <16> ונוסיף שעור הקומה ויצא כל הגובה.

<17> ואם נפל (69b) המעצר בשתי הפעמים על הצל ההפוך הנה הגובה הוא ד' ששיות. <18> ולכן מה שבין המקום הראשון והשרש כמו הגובה וכמו חציו. <19> וכאשר נתקרבנו היה הגובה ה' ששיות מה שבין המקום השני והשרש ולכן הוא כמו הגובה וחמשיתו. <20> נגרע [ה]חמשית[4] מחצי להיות שיתרון הרוחק הגדול מהשרש על הרוחק הקטן הוא כמו חצי הגובה פחות[5] חמישיתו, <21> ונשאר חומש וחצי וזה החומש וחצי הוא מה שמדדנו במה שבין שני המקומות והיה י' אמות.

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[1] An unidentified hand wrote an illegible short marginal note.
[2] It should be ושרש.
[3] It should be הגובה.
[4] Interlineal addition, hand two.
[5] ת written in superscript.

⟨22⟩ We [subtracted][1] 1/5 ⟨of the height from⟩ 1/2 ⟨of the height⟩ and the result is 3/10 ⟨of the height⟩.[2] ⟨23⟩ As 1/5 ⟨of the height⟩ is equivalent to 6 cubits and 2/3 of one cubit,[3] we multiply this [6 and 2/3] by 5 and the product is the value of the height, 33 cubits and 1/3 of a cubit.[4] ⟨24⟩ We have added to them the value of the stature and the result is the true [complete] value of the height ⟨of the object⟩.

⟨XXVIII.4a A more inclusive method for the same situation⟩

⟨1⟩ Another more inclusive short method. ⟨2⟩ Find the difference of the digits between the two ⟨shadows⟩, the ratio of this difference to 12 is the ratio of the cubits ⟨of the distance between the two positions⟩. ⟨3⟩ If the alidade falls once on the straight shadow and once on the inverted, for instance first on 10 digits of the straight ⟨shadow⟩ and, getting farther ⟨from the object⟩, on 11 ⟨digits⟩ of the inverted ⟨shadow⟩, ⟨4⟩ we know that between the first position and the base there are [5/6][5] of the height, and between the second position and the base there is as much as the height and 1/11 of the height. ⟨5⟩ The distance between the two positions is as 1/6 and 1/11 of the height. ⟨6⟩ We shall divide 6—the number by which we divided the height at the beginning—by 11—the number by which we divided it later.[6] ⟨7⟩ This [*lit.* each] ⟨fraction⟩[7] receives 6 divisions of 11 in 1/6. ⟨8⟩ The distance between the two positions is 1/6 of the height and 6 divisions of 11 in 1/6, which is 17⟨/11 in 1/6⟩ of ⟨the height⟩, which are 8 degrees of the 360 of the altitude ⟨scale⟩[8]—⟨equivalent to⟩ 10 cubits[9]—which is what we measured between the two positions; each part [each 11th of 1/6] receives 10 of the 17 divisions in one cubit. ⟨9⟩ We shall multiply this [17/11 in 1/6 of the height] by 11, which is the number by which we divided the sixth. ⟨10⟩ We divide the product by 17 and the result is 1/6 (70a) of the height, ⟨which is equivalent to⟩ 6 cubits and 8 parts of 17 in one cubit. ⟨11⟩ We shall multiply this ⟨quotient⟩ by 6 and the result is the value of the height, ⟨that is,⟩ [38][10] cubits and 14 parts of 17 in one cubit.[11]

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[1] "Subtracted" is my correction of "added," written in the manuscript.

[2] The Hebrew of this sentence is problematic and there are several words crossed out in the MS.

[3] Moses has converted fractions whose denominator is 10 into a fraction whose denominator is 5 multiplying each term of the equation by 2/3.

[4] The distance between the first and the second position is 10 cubits. The formula can be expressed as in XVIII.2, ⟨4⟩: (*HD* / *HGḤ*)*AZ* − (*HD* / *HKḤ*)*AZ* = 10 cubits = (12/8)*AZ* − (12/10)*AZ* = {1+(1/2)}*AZ* −{1 + (2/10)}*AZ* = {1 + (1/2) − 1 − (2/10)}*AZ* = {(1/2) − (1/5)}*AZ* = (3/10)*AZ* = 10 cubits. Hence *AZ* = 10(10/3) = 33 + (1/3) cubits.

[5] "5/6" is my correction of "4/6," written in the manuscript.

[6] The meaning is not clear; he seems to be making the denominators of the two fractions equal by multiplying the first by 11 (= 11/66) and the second by 6 (= 6/66).

[7] I.e., 1/11.

[8] 10 digits of the straight shadow correspond to 50º of the altitude scale and 11 digits of the inverted shadow correspond to 42º of the altitude scale (both, approximately). The difference between these two measures is 8 degrees.

[9] {(1/6) + (1/11)}*AZ* = 10 cubits.

[10] "38" is my correction of "39," written in the manuscript.

[11] For the first measurement we apply the formula used in XVIII.1, ⟨10⟩ and for the second we apply the formula used in XVIII.2, ⟨4⟩. So (*HD* / *HKḤ*)*AZ* − (*HGḤ* / *HD*)*AZ* = 10 cubits = (12/11)*AZ* − (10/12)*AZ* = {1 + (1/11)}*AZ* − (5/6)*AZ* = {1 + (1/11) − (5/6)}*AZ* = (1/6 + 1/11)*AZ* = {(11/6)(1/11) + (6/11)(1/6)}*AZ* = {11 + (6/11)(1/6)}*AZ* = (17/11)(1/6) *AZ* = 10 cubits. If we multiply by 11 then 17(1/6)*AZ* = 110. If we divide by 17 then (1/6)*AZ* = 110/17 = 6 + (8/17) cubits. If we multiply by 6 then *AZ* = 38 + (14/17) = 38.824 cubits (approximately).

<22> {חלקנו}[1] זה {על}[2] חומש ~~ושליש אמה~~[3] {הוספנו}[4] ~~עליהם~~[5] וחצי[6] שהוא ג' עשיריות, <23> ועלה לחומש ו' אמות[7] וב' שלישיות אמה; נכפול זה בה' ועלה שעור הגובה ל"ג אמה ושליש אמה. <24> הוספנו עליהם שעור הקומה ויצא שעור הגובה האמיתי.

<4א.> <1> דרך אחרת קצרה כוללת. <2> דע יתרון האצבעות זה על זה, והנה כערך[8] היתרון ההוא אל י"ב כן ערך האמות. <3> **ואם** נפל המעצר פעם בצל הישר פעם בהפוך כגון שנפל תחלה על י' אצבעות מהישר וכשהתרחקנו נפל על {~~יושר~~}[9] י"א מההפוך, <4> הנה ידענו שמהמקום הראשון עד השרש הוא ד'[10] ששיות הגובה ומהמקום השני עד השרש הוא כמו הגובה וכמו חלק מי"א מחלקי הגובה. <5> הנה מה שבין שני המקומות הוא כמו ששית הגובה וכמו חלק מי"א מחלקיו. <6> נחלק ו' שהוא המספר שנחלק בו ראשונה הגובה על י"א שנחלק בו שנית. <7> והנה נגיע לכל אחד ו' חלקים מי"א בששית. <8> הנה מה שבין שני המקומות הוא ששית הגובה וו' חלקים מי"א בששית שהוא י"ז חלקים מש"ס בגובה והיו אלו הח' חלקים י' אמות כי כן מדדנו בין שתי המקומות, ויגיע לכל חלק י' חלקי<ם> מי"ז באמה. <9> נכפול זה בי"א שהוא שעור שנחלק בהם הששית. <10> ונחלק העולה על י"ז ועלה ששית (70a) הגובה ו' אמות וח' חלקים מי"ז באמה. <11> נכפול זה בו' ועלה שעור הגובה ל"ט[11] אמות וי"ד חלקים מי"ז באמה.

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[1] The word does not make sense in the context.
[2] The word does not make sense in the context.
[3] Crossed out (rightly).
[4] It should be גרענו.
[5] Crossed out (rightly).
[6] It should be מחצי.
[7] ת written in superscript.
[8] Written בערך.
[9] Crossed out (rightly).
[10] It should be ה'.
[11] It should be ל"ח.

⟨12⟩ We have added the value of the stature to it [the product] and the result is the value of the true [i.e., complete] height ⟨of the object⟩.

⟨XXVIII.5 Measuring depth with the shadow square⟩[1]

⟨1⟩ If you want to measure the depth of a pit or something else that is placed lower than you, this must be done necessarily with the shadow square engraved ⟨on the back of an astrolabe⟩. ⟨2⟩ ⟨You⟩ equally ⟨need⟩ the eastern-northern quadrant of the astrolabe and [*lit.* or] to hold the astrolabe from your left hand. ⟨3⟩ When you want to know the depth of a well, stand on its edge and observe the surface of the water through the sighting holes of the alidade on the side ⟨of the well⟩ that is opposite to the side on which you are standing. ⟨4⟩ Look how many digits of ⟨one of⟩ the shadows the alidade intersects. ⟨5⟩ If they are from the digits of the straight ⟨shadow⟩, the ratio of the digits of the shadow to 12 is the ratio of the diameter of the well to the height between your eyes and the surface of the water.[2]

⟨XXVIII.5a Example: Diagram 5⟩

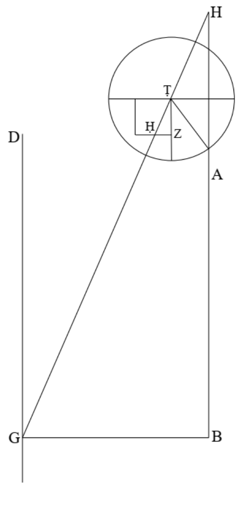

Diagram 5 (MS Paris BnF heb. 1030, f. 70a, on the lower half of the left margin). It shows an outline of the shadow square of an astrolabe and the visual ray of an agent who is measuring with it the depth of a well. *BG* is the diameter of the depth and *HB* is the distance between the observer's eye and the surface of the water in the well. The drawing in the manuscript shows the lines in green ink and the letters in bright red ink. The perimeter of the circumference that represents the astrolabe, not in the original drawing, has been introduced in my diagram following its presence in previous diagrams (see Diagrams 3 and 4a). The shadow falls on the side of the straight shadow, which agrees with the text.

[1] This calculation (XXVIII.5) is also in two of Ibn Ezra's Hebrew versions of his astrolabe text; see MSS Paris BnF heb. 1053, ff. 22b–23a (first version) and Günzburg 937, f. 13b (third version). There are neither examples nor diagrams in Ibn Ezra's texts.

[2] *ZḤ*/*ṬZ* = *BG*/*HB* (in Diagram 5).

<12> הוספנו עליהם שעור הקומה ויצא שעור הגובה האמתי.

<.5> <1> אם רצית מדידת עומק בור או דבר אחר שפל ממך הנה לזה בהכרח יצטרך להיותו מרובע הצללים חקוק, <2> גם כן ברביע המזרחי הצפוני מהאצטרולב או שתתלה האצטרולב ביד שמאלך. <3> וכשתרצה ידיעת עומק הבור עמוד על שפתו והבט שטח המים מנקבי המעצר מצד השפה הנכחית לצד השפה שאתה בה. <4> וראה כמה חתך המעצר מאצבעות הצללים. <5> ואם הוא מאצבעות הישר הנה כערך אצבעות הצל אל י"ב כן ערך קטר הבאר אל הגובה שבין ראותך אל שטח המים.

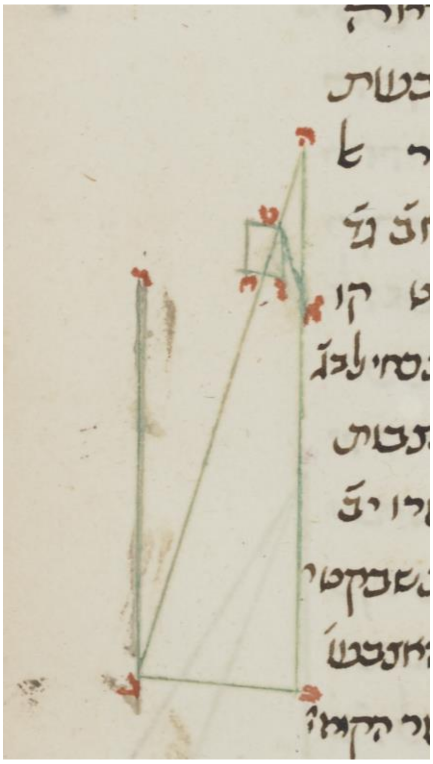

DIAGRAM 5: MS Paris BnF heb. 1030, f. 70a. Photo courtesy of the Bibliothèque nationale de France

⟨1⟩ The well is the surface *ABGD* and line *BG* is on the surface of the water. ⟨2⟩ The visual ray (נצוץ הראות) ⟨starts⟩ at point *H* and the optic ray (נצוץ המבט) is line *HḤG*. ⟨3⟩ The alidade intersects line *ZḤ* of the straight shadow. ⟨4⟩ As the line *ZḤ* is parallel to ⟨line⟩ *BG*, then angle *ZḤṬ* is equal to angle *HGB*,[1] which is opposite to it,[2] and the angles at *Z* and [*B*][3] are right ⟨angles⟩. ⟨5⟩ Triangles *ZḤṬ* and *HGB* are similar and for this reason the ratio of *ZḤ* to *ZṬ*, whose value is 12, is as the ratio of *BG*, which is the diameter of the well, to *HB*. ⟨6⟩ Then let us multiply the cubits of the diameter of the well by 12, which are both the means ⟨of the ratio⟩. ⟨7⟩ We divide the result by the value of the digits ⟨of the straight shadow⟩ and the quotient is the distance between the eyes and the surface of the water. ⟨8⟩ We shall subtract the value of the stature from it [the quotient] and the remainder is the depth of the well. ⟨9⟩ This explanation also serves for the calculation with the inverted shadow.

⟨XXVIII.6 Measuring the width of something with the shadow square⟩[4]

⟨1⟩ When you want to know the width of a river or firth, stand on one bank of the river and observe the opposite side through the sighting holes of the alidade. ⟨2⟩ If the alidade falls between the straight and the inverted shadow⟨s⟩, the width of the river is exactly like your stature. ⟨3⟩ If it falls on the digits of the straight shadow, the ratio of the digits to (70b) 12 is as the ratio of the width of the river to your stature. ⟨4⟩ Then let us multiply the digits ⟨of the straight shadow⟩ by the cubits of the stature; they ⟨both⟩ are the extremes ⟨of the ratio⟩. ⟨5⟩ We shall divide the result by 12 and the quotient is the width of the river under consideration. ⟨6⟩ If the alidade falls on the inverted shadow, the ratio of the digits to 12 is as the ratio of your stature to the width of the river.

[1] Rather, it is the exterior angle (*HGB*) that is equal to the opposite and interior angle (*ZḤṬ*); see Heath 1926, 1:311 (Euclid's *Elements,* Book I Propositon 29).
[2] It is opposite because one is interior (BGH) and the other exterior (ZHṬ).
[3] "*B*" is my correction of "*Ḥ*," written in the manuscript.
[4] This calculation (XXVIII.6) is also in two of Ibn Ezra's Hebrew versions of his astrolabe text; see MSS Paris BnF heb. 1053, f. 23a (first version) and Günzburg 937, f. 13b (third version). There are neither examples nor diagrams in Ibn Ezra's texts.

<5א.> <1> ויהיה הבאר שטח א'ב' ג'ד' וקו ב'ג' על שטח המים, 2 ונצוץ הראות בנקודה ה' ונצוץ המבט קו ה'ח'ג', <3> וחתך הבריח מהצל הישר קו ז'ח'. <4> הנה מפני שקו ז'ח' נכחי לב'ג' הנה זוית ז'ח'ט' שוה לזוית ה'ג'ב' הנגדית אליה וזויות ז'{~~א'~~}[ח'][1] נצבות. <5> הנה משולשי ז'ח'ט' ה'ג'ב' מתדמים ולזה יחס ז'ח' אל ז'ט' ששעורו י"ב כיחס ב'ג' שהוא קטר הבאר אל ~~ה'ט'~~[2] ה'ב'. <6> ולכן נכה האמות שבקטר הבאר עם י"ב שהם האמצעיים <7> ונחלק העולה על שעור האצבעו<ת> ויצא שעור שבין הראות לשטח המים. <8> נגרע ממנו שעור הקומה וישאר שעור עומק הבאר. <9> ובזה יתבאר הענין עם הצל ההפוך.

<6.> <1> כאשר תרצה לדעת רחב נהר או זרועים תעמוד על שפת הנהר ותביט השפה השנית בנקבי המעצר, <2> ואם יפול המעצר במה שבין הצל הישר וההפוך הנה רחב הנהר כשעור קומתך. <3> ואם נפל על אצבעות הצל הישר הנה כיחס האצבעו<ת> אל (70b) י"ב כן [יחס][3] רחב הנהר אל קומתך. <4> ולזה נכה האצבעות עם שעור אמות הקומה שהם הקצוות <5> ונחלק העולה על י"ב ויצא רחב הנהר המוסכל. <6> ואם נפל המעצר על הצל ההפוך הנה כיחס האצבעות אל י"ב כן יחס קומתך אל רחב הנהר.

[1] Interlineal correction, hand two. It should be ב'.
[2] Hand six marked it as wrong (rightly).
[3] Hand nine marked two dots between כן and רחב as an indication for the insertion of an interlineal addition, יחס (of hand two?).

⟨XXVIII.6a Example: Diagram 6⟩

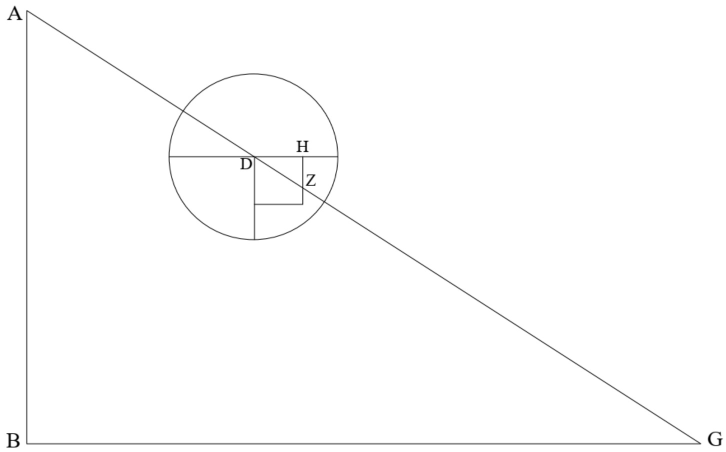

Diagram 6 (MS Paris BnF heb. 1030, f. 70b, on the upper half of the right margin). An outline of the shadow square of an astrolabe and the visual ray going out from the observer standing on one bank of a river to the opposite bank of the same river. *BG* is the width of the river and the observer's stature is *AB*. The drawing in the manuscript shows lines in bright red ink and letters in green ink. The perimeter of the circumference that represents the astrolabe is not in the original but has been introduced following previous diagrams (see Diagrams 3 and 4a). In the original drawing, the shadow of the object falls between the two sides of the square (at the position of an angle of 45º), which is wrong. I have corrected this in my diagram to fit the explanations in the text; the shadow must fall on the side of the inverted shadow.

⟨1⟩ The example is in this diagram in which *BG* is the width of the river, the stature is *AB*, and the digits of the inverted ⟨shadow⟩ are *HZ*. ⟨2⟩ Triangles *DHZ* and *ABG* are similar, given that *AB* and *HZ* are parallel ⟨lines⟩. ⟨3⟩ For this reason, angles *BAG* and *DZH* are alternate [*lit.* exchanged] and equal and the angles at *B* and *H* are right. ⟨4⟩ If this is so, the ratio of *HZ* to *HD*, which is 12 ⟨digits⟩, is as the ratio of *AB* to *BG*. ⟨5⟩ For this reason we shall multiply 12 by the cubits of the stature, which are ⟨both⟩ the means ⟨of the ratio⟩, and divide the result by the digits of the inverted ⟨shadow⟩; the quotient is the unknown width of the river. ⟨6⟩ You ⟨can⟩ also know by this method the distance between you and any place. ⟨7⟩ If we want to know the width of a river without standing on one of its banks, but ⟨standing⟩ far away from them, you find by the previous method the distance between the base of your feet and the other bank of the river; keep it. ⟨8⟩ Find again the distance between your feet and the bank of the river on which you are standing and subtract it from the first. ⟨9⟩ The remainder is the width of the [river].[1]

[1] "River" is my correction of "city," written in the manuscript.

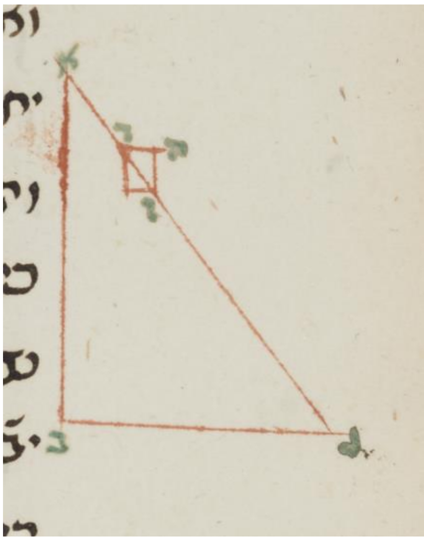

DIAGRAM 6: MS Paris BnF heb. 1030, f. 70b. Photo courtesy of the Bibliothèque nationale de France

<6א.> <1> והמשל בזו התמונה שב'ג' רחב הנהר והקומה א'ב' ואצבעות ההפוך ה'ז' <2> כי הנה משלשי ד'ה'ז' א'ב'ג' מתדמי<ם> כי א'ב' ה'ז' נכחיים. <3> ולזה זויות ב'א'ג' ד'ז'ה' המומרות שוות וזויות ב'ה' נצבות. <4> ואם כן יחס ה'ז' אל ה'ד' שהוא י"ב כיחס א'ב' אל ב'ג'. <5> ולזה נכה י"ב עם אמות הקומה שהם האמצעיים ונחלק העולה על אצבעו<ת> ההפוך ויצא רחב הנהר הנעלם. <6> ובזה יודע הרוחב שממך עד איזה מקום. <7> ואם נרצה לדעת רחב הנהר מבלתי עמוד על שפתו[1] רק רחוק ממנו תדע בדרך הקודם השעור שבין שרש רגלך אל השפה שמהצד האחר מהנהר ושמור זה. <8> עוד דע מה שבין רגלך ושפת הנהר שבצד שאתה עומד בו ונגרע זה מהראשון, <9> והנשאר יהיה רחב העיר[2].

[1] תו written in superscript.
[2] It should be הנהר.

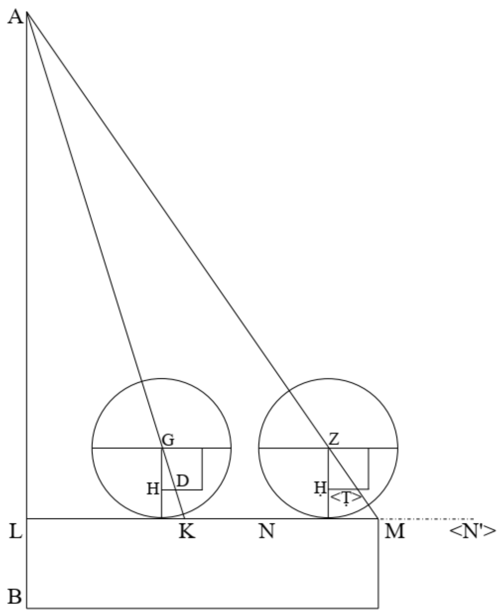

Diagram 7 (MS Paris BnF heb. 1030, f. 70b, on the lower half of the right margin). An outline of the shadow squares on two astrolabes that reproduces the respective positions and relations of the visual ray of the agent when he changes his position between the first and the second observation. His first position is near point *K*, his second is near point *M*. *N* is an intermediate position between *K* and *M*. Letters *Ṭ* and *N'* (a point placed further with respect to *M*) are not in the original drawing of the manuscript but I have introduced them to complete the explanation and facilitate the calculation. The drawing in the manuscript shows lines in green ink and letters in bright red ink. The perimeters of the circumferences that represents the two astrolabes are not in the original but have been introduced following previous diagrams (see Diagrams 3 and 4a). The shadow of the object falls on the side of the straight shadow, which fits the text.

⟨XXVIII.6b More on the previous calculations and their indirect proof (Diagram 7)⟩

⟨1⟩ Now is explained the question we intended to explain above.[1] ⟨2⟩ Let us assume height *AB*; the position of ⟨your⟩ first standing is point *K* and the ⟨position of your⟩ second ⟨standing⟩ is point *M*. ⟨3⟩ The line of the straight ⟨shadow⟩ that the alidade intersected the first time is [*HD*][2] and ⟨the value intersected⟩ the second ⟨time⟩ is line *ṬḤ*. ⟨4⟩ It is already explained in an easy way that triangle *ZḤṬ* and triangle *ALM* are similar, and likewise triangle *GDH* and triangle *AKL*. ⟨5⟩ As the ratio of *DH* to *HG* is as the ratio of *KL* to *AL*, the ⟨corresponding⟩ value [*MK*][3] is added to each—*KL* and *DH*. ⟨6⟩ *DH* with the addition ⟨of the corresponding digits⟩ was the value of the total [*ṬḤ*]. ⟨7⟩ ⟨The ratio of⟩ *ṬḤ* to *HG* [= *ZḤ*] is as the ratio of *KL* plus the difference of their addition [*KM*], which is *LM*, to *AL*.

[1] This sentence may refer to Chapter XXVIII.4a and, more likely, to XXVIII.6a.
[2] "*HD*" is my correction of "*D*," written in the manuscript.
[3] "*MK*" is my correction of "*MH*," written in the manuscript.

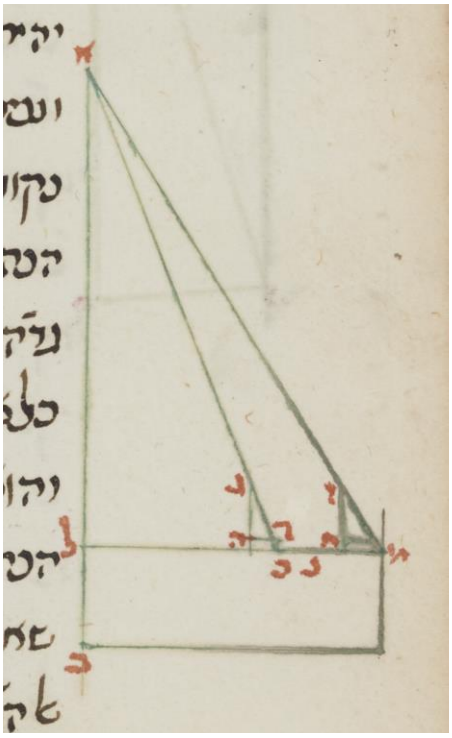

DIAGRAM 7: MS Paris BnF heb. 1030, f. 70b. Photo courtesy of the Bibliothèque nationale de France

<6ב.> <1> **ונבאר** עתה הענין שאמרנו למעלה לבארו. <2> ונניח גובה א'ב' ומקום העמידה הראשונה נקודה כ' והשנית נקודת מ'. <3> ומה שחתך הבריח מהישר בפעם הא' קו ד'[1] ובשנית קו ט'ח'. <4> הנה כבר יתבאר בקלות שמשולש ז'ח'ט' מתדמה למשולש א'ל'מ' ומשלש ג'ד'ה' למשלש א'כ'ל'. <5> ומפני שיחס ד'ה' אל ה'ג' כיחס כ'ל' אל א'ל' ונוסף על כל אחד מכ'ל' ד'ה' שעור מ'ה'[2]. <6> והיה ד'ה' עם הנוסף עליו מקובצים, <7> והוא ט'ח' יחסו אל {ב'}[3] ה'ג' כיחס כ'ל' ויתרונו מקובצים שהוא ל'מ' אל א'ל'.

[1] It should be ה'ד'.
[2] It should be מ'כ'.
[3] Crossed out (rightly).

⟨8⟩ I say that the ratio of the excess of *DH* [= *ṬḤ-DH*] to *HG* [12 digits] is as the ratio of the excess of *KL* [= *ML-KL*], which is *MK*, to *AL*.[1]
⟨9⟩ The proof:[2] if this were not so, the ratio of the excess of *DH* [= *ṬḤ-DH*] to *HG* would be either larger or smaller than the ratio of *MK* to *AL*.[3] ⟨10⟩ ⟨If⟩, to begin, it is smaller, (71a) like *MN*, then the ratio of the excess of *DH* [=*ṬḤ-DH*] to *HG* would be as the ratio of *MN* to *LA*, with the ratio of *DH* to *HG* being equal to the ratio of *KL* to *LA*.[4] ⟨11⟩ According to ⟨Proposition⟩ 24, Book 5 of Euclid, the ratio of *DH* and its excess together [*DH+ṬḤ-DH*], which is *ṬḤ*, to *HG*, equals the ratio of *MN* and *KL* together to *LA*.[5] ⟨12⟩ But the ratio of *ML* to *LA* is as the ratio of *ṬḤ* to [*HG*].[6]
⟨13⟩ According to ⟨Proposition⟩ 11, ⟨Book⟩ 5 ⟨of Euclid⟩, the ratio of *MN* and *KL* added together to *LA* is the smaller.[7] ⟨14⟩ The other value [(*ṬḤ-DH*)/*HG*][8] is the larger ratio of [*MK*][9] to that value [i.e., *LA*], and that is false from ⟨Proposition⟩ 8, ⟨Book⟩ 5 ⟨of Euclid's *Elements*⟩.[10] ⟨15⟩ So it is explained that the ratio of the excess of *DH* to *HG* is not as the ratio of a value larger than *MK* to *AL*.
⟨16⟩ It is clear that being that the case, the ratio of the excess of the digits over the digits to 12 is as the ratio of the distance between the first and the second positions to the height, what was to prove.[11] ⟨17⟩ The inverted shadow is explained in the same ⟨way⟩. ⟨18⟩ There is no need for more diagrams.

It is finished.

From heaven may they have mercy ⟨on me/us⟩.[12]

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[1] Moses calculates height *AL* by subtracting two ratios: (1) *ṬH*/*ZH* = *ML*/*AL* and (2) *DH*/*HG* = *KL*/*AL*. As *HG* = *ZH* = 12, subtracting (2) from (1), one gets (*ṬH-DH*)/12 = (*ML-KL*)/*AL*.
[2] We could call it an "indirect" proof in modern terms.
[3] The author proves XXVIII.6b, ⟨8⟩ by arguing that if the above equation were incorrect, then (*ṬH-DH*)/*HG* would be either larger or smaller than *MK*/*AL*. First, the author pursues the smaller ratio (XXVIII.6b, ⟨10⟩–⟨13⟩): if the ratio is smaller than *MK*/*AL*, then *MK* is smaller, like *MN*. Then he continues with the larger one (XXVIII.6b, ⟨14⟩–⟨15⟩).
[4] *DG*/*HG* = *KL*/*LA* (by the relationship between similar triangles).
[5] Heath 1926, 2:183: "If a first magnitude have to a second the same ratio as a third has to a fourth, and also a fifth have to the second the same ratio as a sixth to the fourth, the first and fifth added together will have to the second the same ratio as the third and sixth have to the fourth."
[6] "*HG*" is my correction of "*AL*," written in the manuscript. So: *ML*/*AL*= (*KL*/*AL*) + (*MK*/*AL*), and since *KL*/*AL* = *DH*/*HG*, and since *MK*/*AL* = (*ML* - *KL*)/*AL* = (*ṬḤ* - *DH*)/*HG*, then *KL*/*AL* + *MK*/*AL* = *DH*/*HG* + (*ṬḤ* - *DH*)/*HG* = *ṬḤ*/*HG* ≠ (*MN* + *KL*)/*AL*. Hence, the smaller value, *MN*, will not work based on what follows from the ratios of the small triangles to the large triangles.
[7] Heath 1926, 2:158: "Ratios which are the same with the same ratio are also the same with one another."
[8] As in XXVIII.6b, ⟨9⟩ referring to the larger value of the ratio.
[9] "*MK*" is my correction of "*ML*," written in the manuscript.
[10] Heath 1926, 2:149: "Of unequal magnitudes, the greater has to the same a greater ratio than the less has; and the same has to the less a greater ratio than it has to the greater."
[11] There is a relationship between the distance from the person to the observed thing and the height of the observed object that the alidade indicates on the shadow square. When the person moves, the ratio of the difference of the distance through which the person moved to the height of the object is the same as the ratio between the two corresponding values indicated by the alidade.
[12] *Talmud Bavli, Avodah zarah* 18a.

<8> הנה אומר שיחס היתרון שעל ד'ה' אל ה'ג' כיחס היתרון שעל כ'ל' שאצל מ'כ' אל א'ל'.

<9> המופת שאם לא כן הנה יהיה יחס יתרון ד'ה' אל ה'ג' כיחס שעור גדול ממ'כ' או קטן אל א'ל'. <10> ויהיה תחלת[1] קטן כמו (71a) מ'נ' יהיה יחס יתרון ד'ה' אל ה'ג' כיחס מ'נ' אל ל'א' ויחס ד'ה' אל ה'ג' כיחס כ'ל' אל ל'א'. <11> הנה מכ"ד מ<אמר> ה' מאיק<לידס> יחס ד'ה' ויתרונו מקובצים שהוא ט'ח' אל ה'ג' כיחס מ'נ' וכ'ל' מקובצים אל ל'א'. <12> אבל יחס מ'ל' אל ל'א' כיחס ט'ח' אל א'ל'[2].

<13> הנה מי"א מה' יחס מ'נ' וכ'ל' מקובצים הקטן אל ל'א'. <14> השעור האחר[3] כיחס מ'ל'[4] הגדול אל השעור ההוא, וזה שקר מח' מה'. <15> וכן יתבאר שאין יחס שעור יתרון ד'ה' אל ה'ג' כמו יחס שעור גדול ממ'כ' אל א'ל'.

<16> הנה יתבאר אם כן שיתרון האצבעות על האצבעות יחסו אל י"ב כיחס מה שבין המקום הראשון והשני אל הגובה ומ<ה> ש<היה> ל<הוכיח>. <17> וכזה יתבאר בצל ההפוך. <18> ואין צורך להרבות בתמונות. ת<ם>. מ<ן> ה<שמים> י<רחמו>.[5]

[1] It should be בתחלה.
[2] It should be ה'ג'.
[3] ר written in superscript.
[4] It should be מ'כ'.
[5] An illegible expression in abbreviated form was added by a tenth? hand to indicate the end of the treatise and something else. The four final Hebrew characters are not clear. I propose a possible reading.

Appendix 1: Abraham Ibn Ezra and Al-Ṣaffār on Telling the Time in Seasonal Hours with an Astrolabe when the Position of the Sun or its Diametrical Opposite Falls between Two Hour Divisions (cf. Moses ben Abraham IV.3, 7–18 and IV.4, 1–2)

Ibn Ezra’s first version	If the diametrical opposite ⟨of the sun⟩ falls somewhere between the two divisions of an hour and you want to find the fraction of the hour, when you place the position of the sun according to ⟨its⟩ altitude, mark on the limb the position of the beginning of Capricorn [or almuri]; this is called the intermediate mark. Place the diametrical opposite of the sun at the beginning of the hour and also mark on the limb the position of the beginning of Capricorn; this is called the first mark. Again place the position of the diametrical opposite of the sun at the end of hour and likewise mark on the limb ⟨the position of the beginning of Capricorn⟩; this is called the last mark. Observe how many degrees [the first preservation] there are between the first and the last marks and between the intermediate and the first marks [the second preservation]; find its ratio to the total number of degrees ⟨of the hour⟩ and you will know the fraction ⟨of the hour⟩.[1]
Ibn Ezra’s second version **Moses ben Abraham’s source**	If you want to know how much of the hour has elapsed, mark on the limb ⟨the position of⟩ the beginning of Capricorn when you calculate the rising degree; this is called the intermediate mark. Take the number of the degree of the sun on the seventh house [i.e., the nadir or diametrical opposite of the sun], already marked, and place it at the beginning of the hour division; mark ⟨the position of the beginning of Capricorn on⟩ the limb [i.e., the first mark]. Do likewise with the end of the hour ⟨and mark the positon of the beginning of Capricorn on the limb⟩. Calculate how many degrees there are between the first and the second marks and keep them [this is the first preservation]. Then, calculate the distance between the intermediate and the first marks [this is the second preservation] and take from the hour what corresponds to this difference. If you want ⟨the elapsed time⟩, divide the distance you have found between the first and the intermediate marks [the second preservation] by sixty and divide [*it should be* multiply] the quotient by the arc of the seasonal hour. You can calculate it by observing how many degrees there are between the

[1] MS Paris BnF heb. 1053, f. 8b (treatise composed in Lucca in 1146): ואם נפל הנוכח באמצע השעה ותרצה לדעת כמה יהיה מן השעה, סמן בתא עם ראש גדי כשתשים מקום השמש על הגובה וזה יקרא סימן אמצעי. וסבב נוכח השמש על תחלת השעה וסמן ג<ם> כ<ן> בתא עם ראש גדי וזה יקרא סימן ראשון. וסבב ג<ם> כ<ן> נוכח השמש על סוף השעה וסמן ג<ם> כ<ן> בתא וזה יקרא סימן אחרון. ותראה כמה מעלות בין הסימן הראשון לאחרון ותראה כמה האמצעי רחוק מן הראשון, ותיחסהו אל כל המעלות ותדע כמה חלק היא ממנו.

	first and the second marks [= the first preservation]; these degrees are called the arc of the seasonal hour. Whatever it be, take its ratio to sixty.[1]
Ibn Ezra's third version	Divide the arc of the day or the arc of the night by twelve; the quotient is the arc of a ⟨seasonal⟩ hour. If the quotient is not ⟨completely⟩ divisible, find the ratio ⟨of the remaining⟩ to twelve and take proportionally from sixty, for the hour is divided into sixty ⟨minutes⟩. Add the result to the number of degrees of the hour. [...] Another way to know how many seasonal hours have elapsed. Place the degree of the sun in the eastern side ⟨of the horizon⟩ and mark the degree that is ⟨its diametrical opposite⟩ in the western side. Also mark on the limb ⟨the position of⟩ the beginning of Capricorn [almuri] and rotate the mark on the western line until you place it at the end of the first hour. Mark on the limb ⟨the position of⟩ the beginning of Capricorn and observe the number of degrees between the two marks of the beginning of Capricorn; it is the number of the seasonal ⟨hours⟩.[2]
Aḥmad ibn al-Ṣaffār's method	Chapter: On the accurate knowledge of the fractions of the hour that have elapsed. If a part of an hour has elapsed and we want to know how much exactly, we mark the position of the almuri on the limb. Then we place the nadir ⟨of the sun⟩ at the beginning of the hour and observe how many degrees the almuri has moved with respect to its previous position. We find the ratio of these degrees to the degrees corresponding to one hour, either diurnal or nocturnal; this proportion is the fraction that has elapsed of the hour, if God wills. If we want to know the degrees of the hour that are left, we also mark the position of the almuri ⟨on the limb⟩ and then place the almuri at the end of the hour. The ratio of the degrees that the almuri has moved to the degrees of the hour gives with accuracy what is left of the hour.[3]

[1] MS BnF heb. 1045, ff. 191a–191b (treatise composed in Verona in 1146): ואם רצית לדעת כמה עברה מן השעה שים סימן עם ראש גדי בתא בהוציאך המעלה הצומחת והוא יקרא סימן אמצעי. וקח מספר מעלת השמש בבית השביעי כי יש עליו סימן ושים אותו על תחלת קו השעה וסמן התא. גם כן תעשה בסוף השעה ודע כמה יש בין הסימן הראשון אל האחרון ושמור אותו. ואחר כן דע כמה הוא הסימן האמצעי רחוק מהסימן הראשון, וקח כדמות אותו הערך מהשעה. ואם תרצה ערוך המרחק שתמצא בין הסימן הראשון ובין הסימן האמצעי על ששים, וחלק (191ב) העולה על קשת השעה המעוותת. ותוכל לדעתה שהסתכל כמה מעלות הם בין הסימן הראשון ובין הסימן האחרון, ואלה המעלות יקראו קשת השעה המעוותת, ומה שיהיה קח ערכו אל ס׳.

[2] MS Moscow Russian State Library Günzburg 937, f. 5b (treatise composed in Béziers in 1148): חלק קשת היום או קשת הלילה על שנים עשר והיוצא היא קשת השעה. ואם ישאר שלא יתחלק, דע מה ערכו אל שנים עשר וקח כדמות אותו הערך מחשבון שישים כי השעה נחלקת לששים. והיוצא תוסיפנו עם מספר מעלות השעה. [...] דרך אחרת לדעת כמה השעות המעוותות. שים מעלת השמש בקו מזרח ועשה סימן במעלה שהיא בקו מערב. גם עשה סימן בחיק עם ראש גדי וסובב הסימן שהוא בקו מערב עד שתשימנו בסוף השעה הראשונה. ועשה סימן בחיק עם ראש גדי וראה מספר המעלות שהם בין שני הסימנין של ראש גדי, וככה מספר המעוותות.

[3] "Capítol sobre el coneixement exacte de les fraccions passades d'una hora. Si ha transcorregut quelcom d'una hora i volem saber què és exactament, posarem un senyal sobre el lloc ocupat per l'almuri al limbus; després posarem el punt del nadir sobre el principi de l'hora, i mirarem quants graus ha variat l'almuri respecte de l'anterior lloc; veurem la proporció que guarda amb els graus corresponents a una hora, diurna o nocturna, i aquesta proporció és el que haurà transcorregut de l'hora, si Déu vol. Si és el que resta de l'hora el que volem saber, posarem també un senyal al lloc ocupat per l'almuri i posarem després l'index a la fi de l'hora, i els graus

Appendix 2: Abraham Ibn Ezra's and an Anonymous Treatise on Finding the Positions of the Moon and the Planets with an Astrolabe by Three Methods (cf. Moses ben Abraham XIII.1–XXIII.4a)

Ibn Ezra's first version	Calculation of the ⟨position of the⟩ moon and the positions of the five planets. Whenever you want to know the position of the moon in the zodiac in an approximate way ⟨at night⟩, take its altitude and also the altitude of one of the ⟨fixed⟩ stars engraved on the rete ⟨that is close to it⟩. This must be at a moment when ⟨both⟩ altitude⟨s⟩ do not change. Place the star pointer among the almucantars according to its altitude. If ⟨the star⟩ is eastern at the moment of taking its altitude, place it among the eastern almucantars; if it is western, place it among the western almucantars. Observe the degree on the almucantar of the altitude of the moon or the planet; this is its position. Pay attention that when you find the moon or any planet in the east, you have to look for ⟨its⟩ degree according to its altitude among the eastern ⟨almucantars⟩, but if you found it in the west, you have to look for ⟨its⟩ degree according to its altitude among the western almucantars. In this way you find its approximate position. You can also find the position of the moon during the day if you care to take its altitude and also the altitude of the sun. Do everything as I already explained with regards to the fixed star, but take the two altitudes at the same moment.[1]
Ibn Ezra's second version **Moses ben Abraham's source**	You can calculate the position of Saturn, Jupiter, Mars, and the moon by three methods. The first ⟨method⟩, when the planet is rising, you take the degree ⟨of longitude⟩ and the altitude of one of the superior planets; find the rising degree ⟨according to what has been explained before⟩ and the planet will be there. The second method, when the planet is setting, you take the degree of the altitude of one of the superior planets. As you know the rising ⟨by the method already explained⟩, you ⟨can also⟩ know the setting ⟨of the planet by the same method⟩. The third method, when one ⟨of the superior planets⟩ is on the ⟨upper⟩ meridian, observe the altitude of the planet. After knowing the quadrant ⟨of the astrolabe⟩ where the planet is located, ⟨move the rete to the position of the

que hagi recorregut l'almuri en proporció als d'una hora, ens donaran exactament el que resta de l'hora," Millás Vallicrosa 1931, 33–34.

[1] MS Paris BnF heb. 1053, f. 14b: בידיעת מקום הירח וידיעת מקום חמשה כוכבי הנבוכה. כשתרצה לדעת מקומם בגלגל המזלות על דרך קרובה קח גבהם וקח ג<ם> כ<ן> גובה כוכב אחד מן הכוכבים המונחים ברשת, ויהיה זה בעת אחת שלא יתחלף הגובה. ושים שן הכוכב הקיים על דמיון גבהו בגשרים. <אם> היה מזרחי בעת לקיחת גבהו שים אותו בגשרים המזרחיים ואם היה מערבי שים אותו בגשרים המערביים. ותביט המעלה שתמצא בגשרים על דמיון הגובה שמצאת הירח או הכוכב הנבוך והוא מומן. ותשמר שאם מצאת הירח או הכוכב הרץ בצד מזרח תבקש המעלה על דמיון גבהו במזרח, ואם מצאת אותו בצד מערב תבקש המעלה על דמיון גבהו במערב ואז תמצא מקומו בקרוב. ותוכל לדעת ג<ם> כ<ן> מקום הירח ביום אם יראה שתקח גבהו ותקח ג<ם> כ<ן> גובה השמש. ותעשה כל מה שהזכרתי בכוכב הקיים ובלבד שתקח שני הגובהים בעת אחת.

	altitude of the planet⟩. Observe the degree of the rete that falls on the ⟨upper⟩ meridian; this is the position of the planet. This method is more correct than that previously mentioned, although all these calculations are approximate when the planet has ⟨ecliptic⟩ latitude, especially if the latitude is large. Only if the planet does not have ⟨ecliptic⟩ latitude is the calculation always accurate. This only happens when the planet is at its northern or southern nodes. If the planet has latitude, you can correct ⟨the calculation⟩ a little if you know the latitude. Observe if the latitude is northern; take two thirds of ⟨the latitude⟩ and subtract them from the degree of the planet; then you get the degree rising with the planet. If the latitude is southern, take two thirds of ⟨the latitude⟩ and add them to the degree of the planet, so you get the degree rising with the planet. You can know the position⟨s⟩ of Venus or Mercury when they rise and when they set. However, you cannot calculate ⟨them⟩ by the meridian method, for Mercury elongates from the sun less than 29 degrees. Likewise, Venus elongates from the sun less than 47 degrees. However, if ⟨the location⟩ is in the seventh clime, which Ptolemy calls *Little Britania* and is below Inglaterra in the west, and the sun is in Capricorn and Venus in Scorpio at the end of the angle, you can calculate ⟨the position of⟩ Venus by ⟨the method of⟩ the meridian, but you cannot in the remaining places ⟨of the world⟩.[1]
Ibn Ezra's third version	The positions of Saturn, Jupiter, or Mars. Observe when the planet is on the ⟨upper⟩ meridian line. The reason is that you observe its altitude until the moment when it starts to decrease. Look for the almucantarat that is on the ⟨upper⟩ meridian line; this is the position of the planet when it is in the ecliptic. You can do likewise at the moment of the rising ⟨of the planet⟩. The reason is that when it rises in the eastern line ⟨of the horizon⟩, you calculate the altitude of one of the superior planets, find the rising degree, and the planet is there. You can do likewise with the setting of the planet. You can also know its position at any hour. Calculate the altitude of one of the three mentioned ⟨superior⟩ planets or of one of the three inferior planets, which are Venus, Mercury, and the moon. Find whether the planet is eastern or western. Calcu-

[1] MS Paris BnF heb. 1045, ff. 192b–193a: תוכל לדעת מקום שבתי וצדק ומאדים והלבנה מג' פנים. האחד בזרוח המשרת תקח מעלות וגבהות אחד הכוכבים העליונים והוצא המעלה הצומחת ושם הכוכב. והדרך השני בשקוע הכוכב שתקח מעלות גבהות אחד מהכוכבים העליונים ובדעתך הזורחת תדע השוקעת. והדרך הג' בהיותו בחצי השמים הסתכל כמה גבהות הכוכב, ואחר שתדע המשרת באי זו רביעית הוא, הסתכל במעלות הרשת אי זה מהן תהיה בחצי השמים, שם הכוכב. וזה הדרך יותר נכונה מהדרכים הנזכרים א<ף> ע<ל> פ<י> שכל אלה הדברים הם על דרך קרובה אם היה לכוכב מרחב ואף כי היה מרחבו הרבה. רק אם לא היה למשרת מרחב תמיד יהיה אמת וזה לא יתכן רק שיהיה המשרת עם ראש תנינו או זנבו. ותוכל לתקן מעט אם היה לו מרחב וידעת כמה מרחבו, שתסתכל (193א) שתסתכל אם היה המרחב שמאלי, קח שתי שלישיותיו וגרע אותם ממעלת הכוכב, אז תמצא המעלה הזורחת עם הכוכב. ואם היה המרחב ימני קח שתי שלישיותיו ותוסיפם על מעלת המשרת, אז תמצא המעלה הזורחת עמו. ותוכל לדעת מקום נגה או כוכב חמה בזרחם גם בשקעם, רק בדרך קו חצי השמים לא יתכן לדעתם בעבור שלא ירחק כוכב חמה מהשמש רק פחות מכ"ט מעלות, גם נגה לא ירחק רק פחות ממ"ז מעלות. אך אם היית בגבול השביעי שיקראנו תלמי ברטגיה הקטנה והוא אחר אינגליטירא בפאת מערב, והשמש במזל גדי ונגה בעקרב בסוף היתד, יתכן להיות גם נגה בחצי השמים, ובשאר המקומות לא יתכן.

	late the degree rising with one of the superior planets as I showed you. Place the zodiac ⟨of the rete⟩ on the ⟨almucantar⟩ degree of the planet in which you are interested and you will find its position. This is correct if the planet does not have latitude; if it has latitude, its position changes. If the planet is in the ⟨upper⟩ meridian, it does not change either. Likewise regarding the positions of the superior planets, you can always calculate them by placing their marks [*lit.* pointers] on the ⟨upper⟩ meridian line; ⟨the position of⟩ the superior planet in longitude will be there. If Saturn or one of its companions [i.e., Jupiter or Mars] are in the rising degree and have latitude, this changes little. If Saturn has northern latitude, it rises two degrees before, and the opposite if the latitude is southern, for in these circumstances the time of its rising is delayed. If Jupiter has northern latitude, it rises about three degrees before its degree, and the opposite if it is southern. If Mars is northern, it follows the rule of its companions ⟨and rises⟩ about four degrees ⟨before or after depending on whether⟩ its latitude is either northern or southern. Like Mars, Venus rises about five degrees ⟨before or after its degree⟩ and Mercury two degrees ⟨before or after its degree depending on whether their corresponding latitudes are either northern or southern⟩.[1]
Hebrew anonymous version of *De utilitatibus astrolabii*	If you want to know the zodiac sign and the degree that the moon is approaching, I am teaching you how to do this in three ⟨different⟩ ways. The first ⟨method⟩: take the altitude of the moon, you shall find it among the almucantars. Take also the altitude of one star that you know and is engraved on your rete and place it among the almucantars according to its altitude. Observe the zodiac sign and the degree approaching the point of the altitude of the moon; this is the degree in which the moon is. The second method: take the days of the moon, i.e., the days elapsed since the new moon, and multiply them by two. Add one to them and divide them by 5. Add to ⟨the position of the new moon⟩ one zodiac sign and 6 degrees per unit ⟨of the number that you have⟩. The place at which the counting ends is the position of the moon. This number has to start from the zodiac sign and the degree in which the sun is ⟨at the day of the new moon⟩.

[1] MS Günzburg 937, f. 9a: מקום שבתאי או צדק או מאדים. הסתכל בהיות הכוכב בקו חצי השמים והטעם שתסכל כמה גבהו עד שיחל לפחות. ובקש הגשר שהוא בקו חצי השמים ושם הכוכב במקום שיגיע חשב האפודה. וככה תוכל לעשות בזרחו והטעם בעלותו עם קו מזרח, שתדע כמה גבהות אחד הכוכבים שהם עליונים והוצא המעלה הצומחת ושם הכוכב. וככה תוכל לעשות בשקוע גם הכוכב. גם תוכל לדעת מקומו בכל שעה שתדע כמה גבהות אחד השלשה הנזכרים גם ככה לשלשה השפלים שהם נוגה וכוכב חמה ולבנה. ותדע אם הוא בצד מזרח או בצד מערב והוצא המעלה הצומחת באחד העליונים כאשר הראיתיך. ושים חשב האפדה על מספר מעלות הכוכב שתרצה, אז תדע מקומו. וזה הדבר הוא נכון אם לא היה לכוכב מרחב, רק אם היה לו מרחב ישתנה מקומו. והנה אם היה בחצי השמים לא יהיה לו שנוי וככה מקומות העליונים כי תוכל לדעת מקומם תמיד שתשים מקום חדודם בקו חצי השמים, שם הכוכב העליון מפאת האורך. והנה שבתאי או חבורין אם היה במעלה הצומחת ויש לו רוחב ישתנה מעט. אם היה שבתאי והוא כל רחבו שמאלי הנה יעלה קודם משתי מעלות והפך הדבר אם היה כל רחבו דרומי כי אז יתאחר עת עלותו. ואם צדק וכל רחבו שמאלי יעלה קודם מעלתו קרוב משלש מעלות, והפך הדבר אם היה כל רחבו דרומי. ואם מאדים כמשפט חברין קרוב מארבע מעלות אם שמאלי אם דרומי, ונוגה קרוב מחמש מעלות וכוכב חמה שתי מעלות.

	The third method: if you want to know the zodiac sign and the degree in which any of the planets [the moon among them] is located, take the altitude of the planet when it is very close to the meridian line, and keep it. Take the degree ⟨of the equator⟩ rising with one of the stars that is engraved on the instrument and also take the hour at which you are making this calculation. Wait until the star [i.e., the planet] leaves the meridian and reaches the altitude that you have kept. Take again the rising degree and the hour with one of the stars. Take the middle between the first rising and the second rising ⟨degrees⟩ with the tooth [the almuri] on the degrees of the mater [i.e., the limb]. The zodiac degree that crosses the meridian line with it is the position of the planet.[1]

Appendix 3: Abraham Ibn Ezra on the Longitude of the Stars (cf. Moses ben Abraham XVIII.1–6)

Ibn Ezra's first version	Calculation of the positions of the large stars in the zodiac. I am writing for you the ⟨stellar⟩ positions as they were in the year 4906 [1146] of the world. Every star shifts its position ⟨according to the tables⟩ one degree every seventy years, that is, they shift fifty-one seconds and twenty-six thirds every year.[2] If you want to know their position in the future, take for every year 51 seconds and 26 thirds and add them to the position of the star as it is written. But if you want to know its position in a moment that is past, take for every year 51 seconds and 26 thirds and subtract them from the position of the star as it is written, then you get its position ⟨at that moment⟩. I write the positions for you and am also giving you a method by which you can recognize them in the sphere. I already let you know that they do not engrave ⟨stars positions⟩ on the rete except for stars of the first or second magnitude. Thus I mention ⟨when⟩ the star ⟨is⟩ of

[1] MS Oxford Bodleian Libraries Opp. 579, f. 61a: אם בקשת לדעת המזל והמעלה אשר הלבנה בקרבו משכילך מפעל זה בג' פנים. הא' קח גבוה הלבנה ותדעה על האלמו<קנטאר>. וקח גם גובה הככב אחד הידוע לך הקבוע ברשתך והצבהו על גבהו באלמו<קנטארט>. וראה המזל והמעלה הנוגעת נקודת גבהות הלבנה היא המעלה אשר בה הלבנה. הפנים הב' קחה ימי הלבנה ר<וצה> ל<ומר> שעברו מן המולד והכפילם. והוסיף עליהם אחד ותחלקם בה'. ותן לה מזל אחד ולכל אחד ו' מעלות. ובמקום אשר תכלה שם המספר שמה הלבנה. המספר ההוא יש להתחיל מן המזל והמעלה אשר בה השמש. והפנים הג' אם חפצת לדעת המזל והמעלה אשר בה אחת מן הככבים הנבוכות קחה גובה הככב בהתקרבו אל קו החצות בסמוך והניחנ<ו> למשמרת. וקחה המעלה הצומחת עם ככב אחד אשר על הכלי וקח גם השעה אשר תפעל בה הפעולה ההיא. והמתן עד אשר תשקע הככב מקום החצות ויבא על עצם הגובה ההיא (sic) אשר הנחת למשמרת. וקחה עוד המעלה הצומחת והשעה עם ככב אחד. וקח האמצעו<ת> בין הצומח<ת> הראשונה ובין השניה עם השן במעלו<ת> האם. והמעלה אשר תבא על קו החצות בה שוכן הככב ההוא.

[2] These are sexagesimal divisions of the degree as they are explained in Abraham bar Ḥiyya's *Sefer ḥešbon mahaleḵot ha-koḵavim*; see Millás Vallicrosa 1959, 27 (Spanish) and 7 (Hebrew). For Abraham Ibn Ezra's *Sefer ha-mispar*, see Silberberg 1895, 42. For a discussion of this precession of 1°/70 years, see Nothaft 2017, 230-232.

	first magnitude, but if nothing is said about the magnitude of a star, then it is of second magnitude [...].[1]
Ibn Ezra's second version	I write for you now the position of the stars in the year of the world 4906 [1146]. It is known that any fixed star shifts its position a degree every seventy years, so it shifts ⟨about⟩ 51 seconds every year. Then, if you want to know the position of a star at a certain moment of the past, look how many degrees there are between the years that elapsed and the year that I mention [1146]. Take 51 seconds, 26 thirds, and 9 tenths for every year; the total is subtracted from the position of the star written ⟨in the tables⟩. If the sought position is after the year that I mention, add the total to the position of the star ⟨in the tables⟩. You should know that the number added or subtracted concerns the longitude; the latitude is always the same. Only the degree of the altitude of the pole changes depending on the longitude; if the star is between the beginning of Aries and the end of Gemini, its altitude increases in the future, but decreases in the past. Between ⟨the beginning of⟩ Cancer and the end of Virgo, ⟨the star⟩ decreases its altitude in the future, but increases it in the past. From the beginning of Libra to the beginning of Capricorn, ⟨the star⟩ decreases its altitude in the future, but increases it in the past. From the beginning of Capricorn to the end of the zodiac, it increases its altitude in the future, but it decreases in the past.[2]

[1] MS Paris BnF heb. 1053, ff. 18a–18b: בידיעת מקום הכוכבים הגדולים שהם בגלגל המזלות. הנה אכתוב לך מקומם כאשר היו בשנת ארבע אלפים ותת"קו לבריאת עולם. ודע כי יעתק כל כוכב ממקומו בכל שבעים שנה מעלה אחת והנה יעתק בכל שנה נ"א שניים וכ"ו שלישיים. ואם תרצא לדעת מקומם בזמן הבא קח לכל שנה נ"א שניים וכ"ו שלישיים ותוסיף אותו על מקום הכוכב כאשר הוא כתו<ב>. ואם רצית לדעת מקומו בזמן שעבר קח לכל שנה נ"א שניים וכ"ו שלישיים ותגרע אותם ממקום הכוכב כאשר הוא כתו<ב>, אז תמצא מקומו. והנה אני אכתו<ב> לך מקומם ואתן לך דרך להכיר (18ב) אותם בגלגל. וכבר הודעתיך כי לא ישימו ברשת כוכבים רק מהכבוד הראשון או השני. והנה הכוכב אשר הוא מהכבוד הראשון אזכיר אותו וכל כוכב שאיני מזכיר מאי זה כבוד הוא דע שהוא מהכבוד השני.

[2] MS Paris BnF heb. 1045, f. 190a: והנה אכתוב לך עתה מקום הכוכבים בשנה ארבעת אלפים ותשע מאות ושש לבריאת עולם. ידוע כי יעתק הכוכב העליון ממקומו בכל שבעים שנה מעלה אחת, והנה יעתק בכל שנה נ"א שניים. והנה אם רצית לדעת מקום הכוכב בזמן שעבר הסתכל כמה יש בין השנים שעברו ובין השנה שהזכרתי, וקח לכל שנה נ"א שניים וכ"ו שלישיים וט" עשיריות, ומה שיתחבר חסרנו מקום הכוכב הכתוב. ואם היה הזמן אחר השנה שהזכרתי תוסף המחובר על מקום הכוכב. ודע כי התוספת או המגרעת היא באורך, רק ברוחב לעולם היא על דרך אחת. רק מעלת גובה הקוטב ישתנה בעבור האורך, כי אם היה הכוכב מראש טלה עד סוף תאומים יוסיף גבהותו בזמן הבא והוא חסר בזמן שעבר. ומסרטן עד סוף בתולה יחסר גבהותו בזמן הבא והוא נוסף בזמן שעבר. ומראש מאזנים עד ראש גדי יחסר גבהותו בזמן הבא והוא נוסף בזמן שעבר. ומראש גדי עד סוף המזלות יוסיף גבהותו בזמן הבא והוא חסר בזמן שעבר.

Appendix 4: Abraham Ibn Ezra and Ibn al-Ṣaffār on Calculating Stellar Positions with an Astrolabe Using the Star Pointers of the Rete (cf. Moses ben Abraham XIX–XX)

Ibn Ezra's first version	Whenever you want to know the degree that is the position ⟨in altitude⟩ of any of the fixed stars ⟨engraved⟩ on the rete and its latitude, place the pointer of the star in the upper meridian and observe the ⟨almucantar⟩ degree of the rete in the upper meridian; the star of your astrolabe is there. The degrees between the pointer of the star and the zodiac is the ecliptic latitude of the star. If the degrees of the rete are more than the degrees of the star, ⟨the star⟩ is southern. If the degrees of the star are more than the degrees of the rete, then ⟨the star⟩ is northern; this is called the ecliptic latitude of the star. The number of degrees it inclines from the equator is called the declination of the star [...]. If you know one of the stars and want to find its position, after finding also its latitude, take its altitude when it is in the upper meridian. This means that you see it go up until it cannot go higher and starts going down; then it is on the upper meridian. Take its altitude ⟨at this moment⟩ and find its latitude; if it is northern, subtract the latitude from the altitude; if it is southern, add the latitude to the altitude. Move the zodiac [the rete] in the ⟨corresponding⟩ quadrant the number of degrees that results after subtracting from or after adding to; you find the quadrant by the position of the sun. The degree that according to the latitude is on the upper meridian after adding to or subtracting from is its position [of the star]. You can also find the position of many stars when they are in conjunction with the planets. You find the position of the planets from the tables; this will also be the position of the star ⟨given that⟩ it is joining ⟨the planet⟩ in conjunction. In this way you can identify the stars when you do not recognize them: consider any large star that you see ⟨engraved on the rete⟩ as if it were one of the visible ones ⟨in the sky⟩. Take its altitude when it is on the ⟨upper⟩ meridian and make the rete turn ⟨accordingly⟩. If the pointer of the star that is similar ⟨to the one visible in the sky⟩ reaches the same altitude, it is the actual star ⟨you see in the sky⟩. If you identify one star, you can identify others. Take the latitude of the star that you know and place its pointer among the almucantars according to its altitude. If the star is eastern at the moment of taking its altitude, place it among the eastern almucantars. If it is western at the moment of taking its altitude, place it among the western almucantars. Take the altitude of one of the large stars that are visible in the sky; if you find the pointer of any star at

	the same altitude, it is the same star, but take the two altitudes at the same time so that the altitude does not change.[1]
Ibn Ezra's second version	If you know the major stars of the zodiac, you can calculate their positions when they are on the ⟨upper⟩ meridian, once you have calculated their latitude, i.e., their distances from the ecliptic, either northward or southward. If they are northern, subtract the latitude of the star from its altitude when it is on the ⟨upper⟩ meridian; if they are southern, add the latitude to the altitude of the star. Move the ecliptic ⟨of the rete⟩ the number of degrees you got after the subtraction or the sum, from the midheaven to the quadrant on which the star is, then you get its position. If you do not have a complete astrolabe, do as I taught you regarding the position of the sun. You can also calculate the position of many of the stars if you know the position of the planets when they [the planet and the star] are in conjunction, even if the latitude of the fixed star and the latitude of the planet are small. However, if one of the latitudes is large, you cannot calculate the true position of the fixed star but with much calculation and effort. You can accurately know the position of the planets from the *Book of the Tables*.[2]
Aḥmad ibn al-Ṣaffār's method	We do likewise to know the altitude of any fixed star on the meridian; we place it on the lower meridian and observe what almucantar of altitude it occupies.[3] Chapter: On the knowledge of the stars that are unknown and are engraved on the rete, based on those known. To know this, we take the altitude of a known star and place it in the corresponding ⟨quadrant and almucantar⟩ according to its altitude. This done, we

[1] MS Paris BnF heb. 1053, ff. 20b–21a: וכאשר תרצה להכיר באי זה מעלה מונח הכוכב אשר בכלי וכמה רחבו, שים שן הכוכב על קו חצי שמים ותעיין המעלה אשר תמצא ברשת על קו חצי <השמים>, שם מונח הכוכב אשר באצטורלב שלך. והמעלות אשר בין שן הכוכב לבין עגולת המזלות הוא מרחב הכוכב. ואם מעלות הרשת יותר ממעלות הכוכב הוא דרומי ואם מעלות הכוכב יותר ממעלות הרשת הוא צפוני, והוא נקרא מרחב הכוכב. ואשר הוא נוטה מעג<ו>לת משוה היום הוא נקרא נטות הכוכב [...]. ואם תכיר כוכב אחד ותרצה לדעת מקומו ואחר שידעת ג<ם> כ<ן> מרחבו, תקח גובהו כאשר הוא בחצי שמים, וזה שתראה אותו עולה עד שאינו לעלות יותר ומתחיל לרדת אז הוא בחצי השמים. ותקח הגובה ותדע המרחב, ואם הוא צפוני גרע המרחב מן הגובה, ואם הוא דרומי הוסף המרחב על הגובה והנשאר או המחובר הסב עגולת המזלות ברביעית ההיא ותגיע (21א) ותגיע לדעת הרביעית ממקום השמש. והמעלה אשר יהיה בקו חצי שמים על מספר הגובה אחר התוספת או המגרעת שם מקומו. וגם תוכל לדעת מקום כוכבים רבים בהתחברים עם המשרתים ותדע מקום המשרתים מלוחות ושם הוא ג<ם> כ<ן> הכוכב המתחבר עמו. ובזה הדרך תוכל להכיר הכוכבים אם לא תכירם, שתחשוב הכוכב הגדול שתראה כאלו הוא כוכב אחד מן הנראה לך ותקח גובהו כאשר הוא הוא בחצי השמים והסב הרשת, אם יגע שן הכוכב אשר דמית על אותו הגובה הוא הכוכב באמת. ואם תכיר כוכב אחד תוכל להכיר אחרים, וזה שתקח גובה הכוכב שתכירו, שים שן הכוכב על הגובה בגשרים. ואם היה הכוכב מזרחי בעת לקחת גובהו שים אותו בגשרי מזרח ואם היה מערבי בעת לקחת גובהו שים אותו על גשרי מערב. וקח גובה כוכב אחד מן הנראה לך שהוא מן הגדולים ותראה, ואם תמצא שן של שום כוכב על אותו הגובה הוא הכוכב בעצמו ובלבד שתיקח שני הגבהים בשעה אחת שלא יתחלף הגובה.

[2] MS Paris BnF heb. 1045, f. 190a: אם תכיר הכוכבים הגדולים שהם בגלגל המזלות תוכל לדעת מקומם בהיותם בחצי השמים אחר שידעת מרחבם, והטעם כמה הם רחוקים מקו גלגל המזלות בצפון או בדרום. ואם הם צפוניים חסר הרוחב מגבהות הכוכב בהיותו בחצי השמים; ואם דרומיים הוסף המרחב על גבהות הכוכב. והנשאר או המחובר הסב גלגל המזלות על מספרו בקו חצי השמים ברביעית שהכוכב שם, אז תמצא מקומו. ואם לא היה כלי הנחשת שלם עשה כאשר למדתיך במקום השמש. גם תוכל לדעת מקום רבים מהכוכבים אם ידעת מקום המשרתים בהתחברם, ואף כי אם היה מרחב הכוכב העליון מעט גם כן מרחב המשרת. רק אם היה אחד מהמרחבים הרבה לא תוכל לדעת מקום הכוכב העליון באמת כי אם בחשבון הרבה ויגיעה גדולה. ומקום המשרתים תוכל לדעתם באמת מספר הלוחות.

[3] "Igualment procedirem per a saber l'altura meridiana d'una estrella, posant-la a la línia de mitja nit i veient quina porció d'altura ocupa a l'almucàntar," Millás Vallicrosa 1931, 35.

	pay attention to the position and almucantar of the star we are looking for and to the corresponding azimuth according to the quadrant in which it falls. We keep these data and adjust the alidade according to the corresponding altitude indicated by the almucantar. We suspend the astrolabe from the hand and observe through the sighting vanes of the alidade in that direction. The star we see, when we observe in this way without moving the alidade, is the sought star.[1]

Appendix 5: Abraham Ibn Ezra on the Calendar Scale on the Back of an Astrolabe (cf. Moses ben Abraham's Chapter II.3)

Ibn Ezra's third version	There are also astrolabes on which they inscribe circles on the back of the mater to know the position of the sun in the zodiac every day of the year. They do it in this way. They inscribe two circumferences close to each other ⟨and one inside the other⟩. There is a small gap between them and the first circle, which is the edge ⟨of the mater⟩. They inscribe on the two circles as many divisions as the degrees of the circumference, i.e., 360, and draw a longer division at the thirtieth ⟨division⟩. They write over them the names of the zodiac signs and start from the west line writing Aries, then Taurus, and then Gemini at the side of the suspensory chain, and so on until the end of the zodiac. They also leave a gap and engrave two [other] circles inside the mentioned circumferences and put 365 divisions between them, the number of the days of the solar year. The counting starts from the line aligned with Aries, at the beginning of the west line, on March 15. Likewise they divide this quadrant, which is southern, until the upper meridian line, on September 16, and the lower one, which is the lower meridian, ⟨on⟩ half December [December 16]. When they want to know in which degree of the zodiac the sun is, they place the endpoint of the bar called the alidade (which is the long tool whose ⟨longitudinal⟩ half is aligned with the sighting vane on the number of the day they want—for they engrave the names of the months according to the number ⟨of their respective days⟩, 30, 31, or 28, which is the month of February) and observe the zodiac degree the bar indicates on the circles; this is the position of the sun. They do the opposite if they want to know what is the day and the month and already know the position of the sun. This is the custom among

[1] "Capítol del coneixement de les estrelles que hom ignora i que estan inscrites a l'aranya, a base de les que hom coneix. Per a saber això, prendrem l'altura d'una estrella coneguda i ho posarem a la part que li correspongui segons la seva altura, i, en fer això, ens fixarem en quin lloc o altura ocupa en l'almucàntar l'estrella que busquem, i l'azimut a què correspon en el quadrant en el qual cau; guardarem aquestes dades i graduarem l'alidada segons l'altura (que ens hauria indicat l'almucàntar); penjarem de la mà l'astrolabi i mirarem a través de les pínules de l'alidada vers aquella direcció, i l'estrella que veiem, així observant, sense moure l'alidada, serà l'estrella buscada," Millás Vallicrosa 1931, 36.

	the artisans from Sepharad and it is needless, for no craftsman can ever make the⟨se⟩ divisions properly. If we say that he has the capability to divide it into equal parts, this is something impossible, because of the excess of the ⟨divisions of⟩ the days over the ⟨divisions of⟩ the degrees. ⟨The solar position⟩ moves a degree because of the intercalation of the Gentiles and also because the sun retrogrades one degree every one hundred and thirty years, for the computation of the year as a ⟨certain⟩ number of complete days and one complete quarter ⟨of day⟩ is not exact, as I will explain in the *Book of the Tables*.[1]

Appendix 6: Abraham Ibn Ezra on the Calculation of the Meridian Altitude of the Sun when the Instrument Is not Complete and the Sun Falls between Two Almucantars (cf. Moses ben Abraham's Chapter VII.3)

Ibn Ezra's second version	If you do not have a complete astrolabe and do not find, on the degree divisions of the (190a) zodiac of the rete, the division at the upper meridian corresponding to the degree of the ⟨solar⟩ altitude, seek the closest division at the upper meridian that is lower than ⟨your⟩ solar altitude. Identify the zodiac degree and mark ⟨the position of⟩ the beginning of Capricorn, which is the pointed tooth, among the degrees of the limb as I explained; this is called the first mark. Afterwards seek the division at the ⟨upper⟩ meridian whose number is ⟨closest and⟩ higher than the degrees of your solar altitude. Mark ⟨on the limb the position of⟩ the beginning of Capricorn; this is called the last mark. Calculate how many degrees there are between the two marks, observe how many degrees there are between your solar altitude at noon and the division whose ⟨altitude⟩ degree is lower than your solar ⟨altitude⟩ and take according to the ratio corresponding to the divisions of the zodiac ⟨that you marked⟩; this is the

[1] MS Günzburg 937, ff. 3a–3b: גם יש כלי הנחשת שישימו שם עגולות באחורי האם לדעת מקום השמש במזלות כל ימות השנה. וככה יעשו, ישימו שתים עגולות קרובות זו לזו והם רחוקות מעט מהעגולה הראשונה שהיא הקיצונה. ויחוקו בשתים העגולות קוים שמספרם שלש מאות וששים כנגד מעלות הגלגל וישימו קוים גדולים אחר כל שלשים. ויכתבו עליהם שמות המזלות ויחלו מתחלת הקו המערבי לכתוב מזל טלה ואחריו שור ואחריו תא<ו>מים לפאת השלשלת, וככה יעשה עד סוף המזלות. גם יכתבו ברחוק מהעגולות הנזכרות שתים עגולות ובין שתיהן קוים שהן שלש מאות וששים וחמשה, כמנין ימות החמה ותחלת המספר מהקו שהוא כנגד מזל טלה בתחלת קו מערב חמשה עשר מחדש מרסו. וככה יחלקו זה הרביע שהוא הדרומי עד שיהיה בקו חצי השמים יום ששה עשר מחדש שטיברי ובקו השפל שהוא קו התהום חצי דבברי. וכאשר ירצו לדעת באי זו מעלה הוא השמש מאי זה מזל ישימו קצה המקצוע הוא הנקרא זרוע הוא הכלי הארוך שאמצעיתו על הנקב על מספר היום שירצו כי יכתבו שמות החדשים כפי מספר כל אחד, אם שלשים או שלשים ואחד או שמנה ועשרים שהוא חדש פליברי, ויסתכלו אנה יגיע המקצוע מעגולות מעלות המזלות ושם השמש. והפך הדבר אם רצו לדעת אי זה יום הוא ובאי זה חדש אם ידעו מקום השמש. ככה משפט (3ב) אומני ספרד ואין צורך כי לעולם לא יוכל אומן לחלק החלקים כהוגן. ואם אמרנו שיש בו יכולת להשוותם ואם הוא דבר השה בעבור תוספת הימים על המעלות, הנה ישתנה מעלה אחת בעבור עבור הגוים ועוד כי ישתנה מהלך השמש לקצה כל מאה ושלשים שנה יום אחד אחורנית בעבור כי חשבון השנה שהיא ימים שלמים ורביעית שלימת איננו בדקדוק יפה, כאשר אפרש בספר הלוחות.

	position of the sun. However, I have to say that this value is approximate, for it is difficult ⟨to calculate it⟩.[1]

Appendix 7: Abraham Ibn Ezra on the Calculation of the Position of the Sun when There Is no Latitude Plate for the Local Horizon of the Observer (cf. Moses ben Abraham's Chapter IX.5 about a Latitude Plate with no Almucantar for One's Latitude)

Ibn Ezra's second version	If you know the latitude of your location, but you do not have a latitude plate calibrated according to it and still want to know how the sun rises in every zodiac sign in your horizon, take a plate for a latitude higher than yours and find the difference of the degrees between the latitudes of the two locations. The degree that you find at the meridian is the number of the zodiac degrees resulting from this subtraction. You can also calculate this with a plate whose latitude is lower than the latitude of your location, but then you have to add the total degrees of the two latitudes and proceed as I showed you.[2]

[1] MS Paris BnF 1045, ff. 189b–190a: ואם לא היה לך כלי שלם ולא תמצא בקוים שהם (190א) מעלות כל מזל ברשת קו שיהיה בחצי השמים על מספר מעלות הגובה, בקש הקו הקרוב אליו שיהיה בחצי השמים עם מספר פחות ממעלות גובה השמש. ודע אי זה מעלה היא מגלגל המזלות ושים סימן ראש גדי, הוא השן החד במעלות התא שהזכרתי, וזה יקרא סימן ראשון. ואחר כן בקש קו שהוא עם חצי השמים שמספרו יותר מגובה מעלות השמש שלך ועשה סימן עם ראש הגדי, וזה הוא הנקרא סימן אחרון. ודע כמה יש בין שני הסימנים והסתכל כמה יש בין גובה מעלות השמש בחצי יומך ובין הקו שהוא פחות מגובה שמשך, וקח כדמות אותו הערך שיש בין קוי מעלות גלגל המזלות ושם מקום השמש. ועוד אפרש לך כדמות זה הערך כי קשה הוא.

[2] MS Paris BnF 1045, f. 190a: ואם ידעת רוחב ארצך ולא יהיה לך לוח ערוך עליו ותרצה לדעת מקום השמש איך יעלה שם בכל מזל ומזל, קח לוח שיהיה יותר מרוחב ארצך וחסר במספר המעלות שיש בין שני מרחבי המקומות, ואשר תמצא בקו חצי השמים כמספר שנשאר שם בגלגל המזלות. גם תוכל לעשותו בלוח שיהיה רחבו פחות ממרחב ארצך שתוסיף המעלות שיש בין שני המרחבים ועשה כאשר הראיתיך.

Appendix 8: Hebrew–English Glossary of Technical Terms Related to Astrolabes in Moses Ben Abraham's Treatise

horizon	אופק (*ofeq*)
sphaera recta	אופק ישר (*ofeq yašar*)
oblique horizon	אופק נוטה (*ofeq noṭeh*)
ecliptic	אופן המזלות (*ofeq ha-mazzalot*) אזור המזלות (*ezor ha-mazzalot*) אפודת המזלות (*afudat ha-mazzalot*)
first eastern almucantar or eastern horizon	אופק המזרח (*ofeq ha-mizraḥ*) אופק מזרחי (*ofeq mizraḥi*)
local horizon	אופק מזרח ומערב (*ofeq mizraḥ u-maʿarav*)
first western almucantar or western horizon	אופק המערב (*ofeq ha-maʿarav*) אופק מערבי (*ofeq maʿaravi*)
horizon of the equator or straight horizon	אופק השווי (*ofeq ha-šivui*)
longitude [astronomical or terrestrial]	אורך (*oreḵ*)
back [of the mater]	אחור (*aḥor* [*em*]) גב (*gav*)
qibla	אלקבלא (*al-qiblaʾ*)
mater [of an astrolabe]	אם (*em*)
cubit [unit of measure]	אמה (*ammah*)

true south [in a local horizon], i.e., the upper meridian	אמצע דרום (*emṣaʿ darom*) אמצע שמים (*emṣaʿ šamayim*) נקודת דרום (*nequddat darom*) נקודת חצי שמים (*nequddat ḥeṣi šamayim*)
true east [in a local horizon]	אמצע מזרח[1] (*emṣaʿ mizraḥ*) נקודת מזרח (*nequddat mizraḥ*)
straight horizon	אמצע מזרח ומערב (*emṣaʿ mizraḥ u-maʿarav*)
true west [in a local horizon]	אמצע מערב (*emṣaʿ maʿarav*)
true north [in a local horizon]	אמצע צפון (*emṣaʿ ṣafon*) נקודת צפון (*nequddat ṣafon*)
mean [terms 2 and 3 of a ratio]	אמצעי (*emṣaʿi*)
digit [unit of measure in the shadow square]	אצבע (*eṣbaʿ*)
astrologers	אצטגנינים (*iṣṭagninim*)
astrological house / place	בית (*bayit*)
alidade	בריח (*beriaḥ*) מעצר (*maʿeṣar*)
altitude [of the sun, a fixed star, or a planet]	גבהות (*gavhut*)
clima	גבול (*gevul*)
altitude / height	גובה (*govah*)

[1] Points east and west of the horizon are diametrical opposites of each other, and the same as regards the points north and south.

circle / sphere	גלגל (*galgal*)
zodiac	גלגל המזלות (*galgal ha-mazzalot*)
sphere of the sun	גלגל השמש (*galgal ha-šemeš*)
eccentric circle [of the sun]	גלגל יוצא מרכז (*galgal yoṣeʾ merkaz*)
deferent circle	גלגל הקפה (*galgal haqqafah*)
almucantar	גשר (*gešer*)
eastern almucantar	גשר מזרחי (*gešer mizraḥi*)
western almucantar	גשר מערבי (*gešer maʿaravi*)
pinnule or sighting vane of the alidade	דף מהמעצר (*daf me-ha-maʿeṣar*)
limb	המקיף (*ha-maqqif*)
external angle	זוית חיצונה (*zavit ḥiṣonah*)
alternate angle	זוית מומרת (*zavit mumeret*)
common angle	זוית משותפת (*zavit meṣotefet*)
opposite/contrary angle	זוית מתנגדת (*zavit mitnaggedet*) זוית נגדית (*zavit negedit*)
acute angle	זוית נדוחת (*zavit nidoḥat*)
right angle	זוית נצבת (*zavit niṣṣevet*)
internal angle	זוית פנימית (*zavit penimit*)

rising [of the sun, a planet, or a fixed star]	זרח (*zaraḥ*) זרוח (*zaruaḥ*) זריחה (*zeriḥah*)
southern planetary node	זנב (*zanav*)
conjunction	חבור (*ḥibbur*)
optics	חכמת ההבטות (*ḥoḵmat ha-habaṭot*)
division of the ecliptic into the twelve astrological houses	חלוק הבתים (*ḥilluq ha-battim*) להשוות הבתים (*le-hašvot ha-battim*)
noon / meridian / midday	חצי יום (*ḥeṣi yom*)
midnight	חצי לילה (*ḥeṣi lailah*)
radius	חצי קטר עגולה (*ḥeṣi qoṭer ʿagullah*)
midheaven / upper meridian	חצי שמים (*ḥeṣi šamayim*)
lower meridian	חצי השמים שתחת האופק *ḥeṣi ha-šamayim še-taḥat ha-*) (*ofeq* יתד הארץ (*yeted ha-areṣ*)
centre	טבור (*ṭabur*) מרכז (*merkaz*)
ring of the astrolabe [a component of the suspensory part]	טבעת (*ṭabaʿat*)
inhabited world	יישוב (*yišuv*)
angle / *cardo*	יתד (*yated*)
angle of the earth / lower meridian / fourth astrological house	יתד הארץ (*yeted ha-areṣ*)

angle of the midheaven / tenth astrological house	יתד השמים (*yeted ha-šamayim*)
sphere (heavenly or of the Earth)	כדור (*kaddur*)
power (astrological notion)	כח (*koaḥ*)
fixed star / planet	ככב (*koḵav*)
planet	ככב רץ (*koḵav raṣ*)
fixed star	ככב קיימי (*koḵav qayyemi*)
astrolabe	כלי (*keli*) כלי אצטרולב (*keli aṣṭrolab/iṣṭrolab*) כלי נחשת (*keli neḥošet*) כלי הבטה (*keli habaṭah*) אצטרולב (*aṣṭrolab/iṣṭrolab*)
medial astrolabe (incomplete astrolabe)	כלי חצי (*keli ḥaṣi*)
tertial astrolabe (incomplete astrolabe)	כלי שליש (*keli šeliš*)
complete astrolabe	כלי שלם (*keli šalem*)
latitude plate	לוח (*luaḥ*) לוח ארץ (*luaḥ areṣ*)
eclipse	לקות (*lequt*)
indicator (*almuri*) = tooth at the beginning of Capricorn in the rete	מורה (*moreh*) ראש גדי (roš Gedi)
zodiac sign	מזל (*mazzal*)

zodiac sign of long ascension [those placed between the beginning of Cancer and the end of Sagittarius]	מזל ארוך המצעד (*mazzal aruḵ ha-miṣʿad*)
southern zodiac sign	מזל דרומי (*mazzal deromi*)
northern zodiac sign	מזל צפוני (*mazzal ṣefoni*) מזל שמאלי (*mazzal semoli*)
zodiac sign of short ascension [those placed between the beginning of Capricorn and the end of Gemini]	מזל קצר המצעד (*mazzal qaṣar ha-miṣʿad*)
chord	מיתר (*meitar*)
sine	מיתר מחוצה (*meitar meḥuṣah*) מיתר מחוצה אל קשת (*meitar meḥuṣah el qešet*)
sine of the complementary arc	מיתר מחוצה לקשת שארית (*meitar meḥuṣah le-qešet šeʾerit*)
diametrical opposite of the solar degree or nadir	מעלה נכחית למעלת השמש (*maʿalah noḵeḥit le-maʿalah ha-šemeš*) נכח מעלת השמש (*noḵaḥ maʿalat ha-šemeš*) נכח השמש (*noḵaḥ ha-šemeš*)
rising degree or ascendant	צומחת (*ṣomeḥet*) מעלה צומחת (*maʿalah ṣomeḥet*)
solstices	מעלות מתחלפות (*maʿalot mitḥallefot*)
to culminate with a degree ⟨of the ecliptic⟩	מצעו האשמים עם/ב (*maṣṣeʿu ha-šamayim ʿim/be*) מצע עם מעלה (*maṣaʿ ʿim maʿalah*)
projection	מקיש (*maqiš*)
diagram proposition	תמונה (*temunah*)

[shadow] square	מרובע (*meruba*ʿ) מרובע הצללים (*meruba*ʿ *ha-ṣelalim*)
celestial latitude with respect to the zodiac or the equa-tor	מרחב (*merḥav*)
latitude [of a location]	מרחק (*merḥaq*)
equator circle of the equator	משוה (*mašveh*)
similar triangle[1]	משלש מתדמי (*mešullaš mitdemi*)
planet	משרת (*mešaret*)
declination [of the sun or any degree of the zodiac]	נטייה (*neṭiyyah*)
zenith [of any horizon]	נכח (*nokaḥ*) נכח ראש (*nokaḥ roš*) נקודת הראש *(nequddat roš*)
straight alignment/direction (equivalent to *qibla*)	נכחות (*nokeḥut*)
parallel	נכחי (*nokeḥi*)
visual ray	נצוץ מבט (*niṣuṣ mabbaṭ*)
optic ray	נצוץ ראות (*niṣuṣ re*ʾ*ut*)
sighting holes in the pinnules of the alidade	נקבי אצטרולב (*neqavei aṣṭrolab*) נקבי מעצר (*neqavei ma*ʿ*eṣar*) נקבי בריח (*neqavei beriaḥ*)
equinox	נקודת המשוה (*nequddat ha-mašveh*) נקודת השווי שוה (*nequddat ha-šivui šaveh*)

[1] Similar triangles have all their angles equal and their corresponding sides have the same ratio.

morning twilight	נשף יום (*nešef yom*)
evening twilight	נשף לילה (*nešef lailah*)
azimuth (use as a sing. even if the Hebrew word reproduces the Arabic plural form)	סמות (*samut* pl.) סמת (*samt* sing.) סומת (*sumt* pl.) סימת (*simt* pl.)
circle	עגולה (ʿ*agullah*)
great circle of the sphere	עגולה גדולה (ʿ*agullah gedolah*) עגולה היותר גדולה (ʿ*agullah ha-yoter gedolah*)
circle parallel to the horizon	עגולה נכחית לאופק (ʿ*agullah nok̲eḥit la-ofeq*) עגולה נכוחית לאופק (ʿ*agullah nek̲oḥit la-ofeq*)
circle parallel to the equator	עגולה נכחית למשוה (ʿ*agullah nok̲eḥit la-mašveh*) עגולה נכוחית למשוה (ʿ*agullah nek̲oḥit la-mašveh*)
circle of the horizon	עגולת האופק (ʿ*agullat ha-ofeq*)
circle of the right horizon	עגולת אופק השווי (ʿ*agullat ofeq ha-šivui*)
altitude scale (on the back of an astrolabe)	עגולת הגובה (ʿ*agullat ha-govah*)
circle of the meridian	עגולת חצי היום (ʿ*agullat ḥeṣi ha-yom*) עגול חצי היום (ʿ*iggul ḥeṣi ha-yom*)
circle of the equator or equator	עגולת המשוה (ʿ*agullat ha-mašveh*) עגולת השווי (ʿ*agullat ha-šivui*) עגול משוה (ʿ*iggul mašveh*)

equinoctial colure	עגולת משוה היום (ʿ*agullat mašveh ha-yom*) עגול ראש טלה (ʿ*iggul roš Ṭaleh*)
circle of the zodiac or ecliptic	עגולת המזלות (ʿ*agullat ha-mazzalot*)
circle of the zenith	עגולת נכח הראש (ʿ*agullat nok̲aḥ ha-roš*)
zodiac or ecliptic [of the rete]	עגול המזלות (ʿ*iggul ha-mazzalot*)
Tropic of Capricorn or winter Tropic [*lit.* the circle of the beginning of Capricorn]	עגול ראש גדי (ʿ*iggul roš Gedi*)
superior planet (any of those placed above the sun: Mars, Jupiter, and Saturn)	עליון (ʿ*elion*)
rise ascension	עלייה (ʿ*aliyyah*) מעלה (*maʿaleh*)
gnomon [proper meaning] shadow [another meaning in Moses' text]	עמוד (ʿ*amud*)
horizontal gnomon (related to the inverted/vertical shadow)	עמוד הפוך (ʿ*amud hafuk̲*)
vertical gnomon (related to the straight/horizontal/extended shadow)	עמוד נצב (ʿ*amud niṣṣav*)
front of the astrolabe	פני האצטרולב (*penei ha-aṣṭrolab/iṣṭrolab*)
shadow	צל (*ṣel*)
inverted shadow or *umbra versa*	צל הפוך (*ṣel hafuk̲*) עמוד הפוך (ʿ*amud hafuk̲*)
straight shadow or *umbra recta* or horizontal/extended shadow	צל ישר (*ṣel yašar*) צל נפרש (*ṣel nifras*) עמוד ישר (ʿ*amud yašar*)
first eastern almucantar	קו האופק המזרחי (*qav ha-ofeq ha-mizraḥi*)

line of the horizon or first almucantar	קו האופק (*qav ha-ofeq*)
line of the straight horizon [i.e. the east-west line of the latitude plate]	קו אמצע מזרח ומערב (*qav emṣaʿ mizraḥ u-maʿarav*) קו האופק הישר (*qav ha-ofeq ha-yašar*) קו הולך ממזרח למערב (*qav holek̲ me-mizraḥ le-maʿarav*)
first western almucantar	קו האופק המערבי (*qav ha-ofeq ha-maʿaravi*)
first almucantar	קו האופק הראשון (*qav ha-ofeq ha-rišon*)
upper meridian line or midheaven	קו אמצע השמים (*qav emṣaʿ ha-šamayim*) קו חצי היום (*qav ḥeṣi ha-yom*) קו חצי השמים (*qav ḥeṣi ha-šamayim*)
azimuthal line	קו קדקד (*qav qodqod*)
limb	קו סובב (*qav sovev*) תא (*taʾ*)
east line [of the horizon on the latitude plate]	קו מזרחי (*qav misraḥi*)
fiducial line [of the alidade]	קו מעצר (*qav maʿeṣar*) קנה מעצר (*qanah maʿeṣar*)
pole	קוטב (*qoṭev*)
pole of the horizon	קוטב האופק (*qoṭev ha-ofeq*)
pole of the straight horizon	קוטב האופק השווי (*qoṭev ha-ofeq ha-šivui*)
southern pole [of the horizon]	קוטב דרומי (*qoṭev deromi*)
pole of the equator	קוטב משוה (*qoṭev mašveh*)

northern pole [of the horizon]	קוטב צפוני (*qoṭev ṣefoni*)
pole of the world	קטב העולם (*qoṭev ha-ʿolam*)
east point [of the horizon]	קצה מזרח (*qeṣah mizraḥ*) קצה מזרחי (*qaṣeh mizraḥ*i)
extreme [terms 1 and 4 of a ratio]	קצוות (*qaṣeh*)
arc	קשת (*qešet*)
diurnal arc	קשת יום (*qešet yom*) קשת יומית (*qešet yomit*)
nocturnal arc	קשת הלילה (*qešet lailah*) קשת לילית (*qešet leilit*)
similar arcs	קשתות מתדמות (*qešetot mitdamot*)
cusp of an astrological house	ראש בית (*roš bayit*) תחלת בית (*teḥilat bayit*)
equinox [*lit.* the beginning of Aries or Libra]	ראש טלה או מאזנים (*roš Ṭaleh o Moznayim*)
winter solstice [*lit.* the beginning of Capricorn] almuri or indicator	ראש גדי (*roš Gedi*)
summer solstice [*lit.* the beginning of Cancer]	ראש סרטן (*roš Sarṭan*)
quarter [each of the four quarters into which the year is divided according to the solstices and equinoxes]	רביע (*reviʿa*) רביעית השנה (*reviʿit ha-šanah*)
quadrant [each of the four quarters into which the horizon projected on an astrolabe is divided]	רביעי (*reviʿi*)
quadrant [each of the four delimited on the latitude plate by the east-west and the meridian lines]	רובע (*rovaʿ*)

latitude [of a place]	רוחב (*roḥav*)
rete	רשת (*rešet*) שבכה (*sevaḵah*)
descendant	שוקעת (*šoqaʿat*)
setting, descending [of the sun or a planet]	שוקעת (*šoqaʿat*) שקיעה (*šeqiʿah*) שקוע (*šiqquʿah*)
projection [onto a plane] surface plane	שטח (*šeṭaḥ*)
to project [circles onto a plane]	השטיח (*hišṭiaḥ*)
star pointer of the rete	שן ככב (*šen koḵav*)
equinoctial hour	שעה ישר (*šaʿah yašar*) שעה שוה (*šaʿah šavah*)
seasonal hour	שעה מעוות (*šaʿah meʿuvat*)
diurnal seasonal hour	שעה מעוות יומית (*šaʿah meʿuvat yomit*)
nocturnal seasonal hour	שעה מעוות לילית (*šaʿah meʿuvat leilit*)
minimum altitude [of the sun or any star on the horizon]	שפלות (*šifelut*)
suspensory part [of an astrolabe]	תלייה (*teliyyah*)
general motion [of the heavens] or daily motion	תנועה כללית (*tenuʿah kelalit*)
northern planetary node	תנין (*tannin*)

References

Manuscript Sources

Berlin, Staatsbibliothek Ahlwardt 5805

Jerusalem, National Library of Israel Heb. 3573

Jerusalem, National Library of Israel Heb. 3906=8

Jerusalem, National Library of Israel Heb. 3961=8

Jerusalem, National Library of Israel Heb. 3982=8

Jerusalem, National Library of Israel Meir Benayahu O 131

London, British Library Add. 9600

London, British Library Alm. 96 II

Madrid, Biblioteca nacional de España 5474

Moscow, Russian State Library Günzburg 937

New York, Jewish Theological Seminary of America 6728

Oxford, Bodleian Libraries Opp. Add. Qu. 160

Oxford, Bodleian Libraries Opp. 579

Oxford, Bodleian Libraries Opp. 697

Oxford, Bodleian Libraries Opp. Add. 4º 175

Paris, Bibliothèque nationale de France heb. 1030

Paris, Bibliothèque nationale de France heb. 1047

Paris, Bibliothèque nationale de France heb. 1053

Paris, Bibliothèque nationale de France heb. 1095

Paris, Bibliothèque nationale de France heb. 959

San Lorenzo de El Escorial, Biblioteca del Real Monasterio 964

St. Petersburg National Library of Russia EVR I 320b

Non-Manuscript Sources

a. Printed Sources

Beinart, Haim, 1981. *Conversos on Trial: The Inquisition in Ciudad Real*, Jerusalem.

— 2007a (2nd edition). “Ciudad Real,” in *Encyclopaedia Judaica*, ed. F. Skolnik and M. Berenbaum, 22 vols., Detroit, 4:745.

Beinart, Haim, Assis, Yom Tov, 2007b (2nd edition). “Ciudad Rodrigo,” in *Encyclopaedia Judaica*, ed. F. Skolnik and M. Berenbaum, 22 vols., Detroit, 4:745.

Ben-Naeh, Y., 2008. *Jews in the Realm of the Sultans. Ottoman Jewish Society in the Seventeenth Century*, Tübingen.

Berggren, J.L., Jones, A., 2000. *Ptolemy’s Geography: An Annotated Translation of the Theoretical Chapters*, Princeton, N.J.

Brumer, J., 1984–1986 [repr. 2009]. *Catalog of Rabbinic Manuscripts of the Jewish Theological Seminary of America*, New York, vol. 4.

Cassel, D., 1846. *Zikron Yehudah*, Berlin (online *Responsa Project*)

Chabás Bergón, J., 2011. “Interactions between Jewish and Christian astronomers in the Iberian Peninsula,” in *Science in Medieval Jewish Cultures*, ed. Gad Freudenthal, Cambridge, 147–154.

Chabás Bergón, J., Goldstein, B.R., 2014. *Essays on Medieval Computational Astronomy*, Leiden.

Czinczenheim, C., 2000. *Édition, traduction et commentaire des Sphériques de Théodose*, PhD dissertation, University of Paris 4 (Sorbonne), Paris.

Delgado Merchán, L., 1907. *Historia documentada de Ciudad Real (la judería, la Inquisición y la Santa Hermandad)*, Ciudad Real.

Eichenbaum, Miriam, 2021. *Abraham Ibn Ezra: Sefer keli ha-neḥošet, Scientific and Annotated Edition of the Three Hebrew Versions*, PhD dissertation, Bar Ilan University, Ramat Gan.

Elior, O., 2021. *Euclid’s Elements in Hebrew Garb—Critical Editions of the Translation by Moses Ibn Tibbon and the Translation ascribed to Rabbi Jacob, with an Introduction and Glossary, Books I-II*, Leiden.

García Casar, M.F., 1992. *El pasado judío de Ciudad Rodrigo*, Salamanca.

Goldstein, B.R., 1979. “The Survival of Arabic Astronomy in Hebrew,” *Journal for the History of Astronomy* 3, 31–39.

— 1985. *The astronomy of Levi ben Gerson (1288–1344),* New York.

— 2020. “Some Late Medieval Tables in Hebrew for Planetary Equations,” *Suhayl* 18, 129–159.

Grant, E., 1996. *The Foundations of Modern Science in the Middle Ages: Their Religious, Institutional and Intellectual Contexts*, Cambridge.

Hacker, J., 2007 (2nd edition). “Mizraḥi, Elijahu,” in *Encyclopaedia Judaica*, ed. F. Skolnik and M. Berenbaum, 22 vols., Detroit, 14:393-395.

Heath, T.L., 1926 (2nd edition, reprint 1956). *The Thirteen Books of Euclid's Elements Translated from the Text of Heiberg with Introduction and Commentary*, 3 vols. Cambridge.

King, D., 1990. “A Survey of Medieval Islamic Shadow Schemes for Simple Time-Reckoning,” *Oriens* 32, 191–249.

— 1999. *World-Maps for Finding the Direction and Distance of Mecca—Innovation and Tradition in Islamic Science*, Leiden.

— 2004. *In Synchrony with the Heavens—Studies in Astronomical Timekeeping and Instrumentation in Medieval Islamic Civilization*, 2 vols., Leiden.

Klein, I., Horowitz, Y., 2007 (2nd edition). “Ẓahalon,” *Encyclopaedia Judaica*, ed. F. Skolnik and M. Berenbaum, 22 vols., Detroit, 21:444–445.

Kunitzsch, P., 1959. *Arabische Sternnamen in Europa*, Wiesbaden.

— 1989. “On the authenticity of the treatise on the composition and use of the astrolabe ascribed to Messahalla,” in *The Arabs and the Stars: Texts and Traditions on the Fixed Stars and Their Influence in Medieval Europe*, Northampton, 1989 [reprint of *Archives internationales d'histoire des sciences* 31 (1981), 42-62.

— 1993. “Fragments of Ptolemy's Planisphaerium in an Early Latin Translation,” *Centaurus* 36, 97–101.

Kunitzsch, P., Lorch, R., 2010. *Theodosius' Sphaerica: Arabic and Medieval Latin translations*, Stuttgart.

Kunitzsch, P., Smart, T., 2006. *Dictionary of Modern Star Names: A Short Guide to 254 Star Names and Their Derivations*, Cambridge.

Langermann, Y.T., 2011. “Science in the Jewish Communities of the Byzantine Cultural Orbit: New Perspectives,” in *Science in Medieval Jewish Cultures*, ed. Gad Freudenthal, New York, 438–453.

Lehmann, M.B., 2005. *Ladino Rabbinic Literature and Ottoman Sephardic Culture*, Bloomington.

Levy, A., 1994. “The Ottoman-Jewish Symbiosis in the Fifteenth Century,” in *The Jews of the Ottoman Empire*, ed. Avigdor Levy, Princeton, N.J., 13–41.

Lévy, T., 1997a. “Une version hébraïque inédite des Éléments d'Euclide,” in *Les voies de la science grecque: Études sur la transmission des textes de l'Antiquité au dix-neuvième siècle*, ed. Danielle Jacquart, Genève, 181–239.

— 1997b. “Les Éléments d'Éuclide en hébreu (XIIIe–XVIe siècles),” in *Perspectives arabes médiévales sur la tradition scientifique et philosophique grecque: Actes du* *colloque de la SIHSPAI (Société Internationale d'Histoire des Sciences et de la Philosophie Arabes et Islamiques), Paris 31 mars– 3 avril 1993*, ed. Ahmad Hasnawi, Abdelali Elamrani-Jamal, and Maroun Aouad, Leuven, 79–94;

Lévy, T., Burnett, Ch., 2006. "Sefer ha-Middot: A Mid-Twelfth-Century Text on Arithmetic and Geometry Attributed to Abraham Ibn Ezra," *Aleph: Historical Studies in Science and Judaism* 6, 57–238.

Lindberg, D.C., 1976. *Theories of Vision from Al-Kindi to Kepler*, Chicago.

Lorch, R., 1995. "Ptolemy and Maslama on the Transformation of Circles into Circles in Stereographic Projection," *Archive for the History of Exact Sciences* 49, 271–284.

— 1996. "The Transmission of Theodosius Sphaerica," in *Mathematische Probleme im Mittelalter. Der lateinische und arabische Sprachbereich*, ed. Menso Folkerts, Wiesbaden, 159–183.

— 2014. "The Second Arabic Translation of Theodosius' Sphaerica," in *From Alexandria Through Baghdad–Surveys and Studies in the Ancient Greek and Medieval Islamic Mathematical Sciences in Honor of J.L. Berggren*, ed. Nathan Sidoli and Glen Van Brummelen, Berlin, 255–258.

Millás Vallicrosa, J.M., 1931. *Assaig d'història de les idees físiques i matemàtiques a la Catalunya medieval*, Barcelona.

— 1943–50. *Estudios sobre Azarquiel*, Madrid.

— 1949. *Estudios sobre Historia de la Ciencia Española*, Madrid.

— 1955. "Los primeros tratados de astrolabio en la España árabe," *Revista del Instituto Egipcio de Estudios Islámicos* 3, 35–49 and 47–76.

— 1959. *La obra Séfer Hešbón mahlekot ha-kokabim—Libro del calculo de los movimientos de los astros de R. Abraham bar Ḥiyya ha-Bargeloní*, Barcelona.

Munk, M., et al., 1866. *Catalogue des manuscrits hébreux et samaritains de la Bibliothèque impériale*, Paris.

Munk, S., 1908. "Manuscrits hébreux de l'Oratoire, a la Bibliothèque nationale de Paris. Notices inédites," *Zeitschrift für hebraeische Bibliographie* 12, 157–159.

— 1911. *Manuscrits hébreux de l'Oratoire a la Bibliothèque nationale de Paris*, Francfort-sur-le-Mein.

Nallino. C.A., 1899–1907. *Al-Battānī sive Albatenii—Opus Astronomicum*, 3vols., Milan.

Neubauer, A., Beit-Arié, M., May, R.A., 1994. *Catalogue of the Hebrew manuscripts in the Bodleian Library: Supplement of Addenda and Corrigenda to Vol. I*, Oxford.

Neubauer, A., Cowley, A.E., 1886-1906. *Catalogue of the Hebrew manuscripts in the Bodleian Library and in the college libraries of Oxford*, 2 vols., Oxford.

Nothaft, Ph., 2017. “Criticism of Trepidation Models and Advocacy of Uniform Precession in Medieval Latin Astronomy,” *Archive for the History of Exact Sciences* 71, 211-244.

Robinson, James T., Melammed, Uri, 2007 (2nd edition). “Tibbon, Ibn (Tibbonids),” *Encyclopaedia Judaica*, ed. F. Skolnik and M. Berenbaum, 22 vols., Detroit, 19:712–714, at 712.

Rodríguez-Arribas, J., 2014. “Medieval Jews and Medieval Astrolabes: Where, Why, How, and What for?,” in *Time, Astronomy, and Calendars in Jewish Tradition*, ed. Sacha Stern, Leiden, 221–272.

— 2015. “Quantitative Concepts in Hellenistic and Medieval Astrology,” *From Masha’allah to Kepler*, ed. Ch. Burnett and Dorian Gieseler Greenbaum, London, 325–352.

— 2016. “Reading Astrolabes in Medieval Hebrew,” in *Language as a Scientific Tool, Shaping Scientific Language Across Time and National Traditions*, ed. J. Feichtinger, M. MacLeod, and al, New York, 89–112.

— 2018. “A Treatise on the Construction of Astrolabes by Jacob ben Abi Abraham Isaac al-Corsuno (Barcelona, 1378): Edition, Translation, and Commentary,” *Journal for the History of Astronomy* 49-1, 27–82 (Hebrew edition available only online at https://journals.sagepub.com/doi/suppl/10.1177/0021828618755773).

Rodríguez-Arribas, J., Kozodoy, M., 2020. “Joseph ben Solomon Ṭaiṭaṣaq on the Construction of an Astrolabe: Study, Diplomatic Edition, and Annotated Translation,” *Aleph Historical Studies in Science and Judaism* 20-1, 7–101.

Rozen, M., 2010. *A History of the Jewish Community in Istanbul—The Formative Years, 1453–1566*, Leiden.

Schmidl, P.G., 2015. “Islamic Folk Astronomy,” in *Handbook of Archaeoastronomy and Ethnoastronomy*, ed. Clive L.N. Ruggles, New York, 1927–1934.

Schub, P., 1932. “A Mathematical Tract by Mordecai Comtino,” *Isis* 17, 54–70.

Sed-Rajna, G., 1994. *Les manuscrits hébreux enluminés des bibliothèques de France*, Leuven.

Sela, S., 2003. *Abraham Ibn Ezra and the Rise of Medieval Hebrew Science*, Leiden.

— 2019. “Abraham Ibn Ezra as the Translator of Astrological and Astronomical Texts from Arabic into Hebrew: Sources and Methods,” *Medieval Encounters* 25, 345–380.

Šeʾeilot u-tešuvot me-rabbi Yosef ben Lev, vol. 3 (online *Responsa Project*).

Shefer-Mossensohn, M., 2015. *Science Among the Ottomans: The Cultural Creation and Exchange of Knowledge*, Austin.

Sheynin, H.Y., 2015. "Claudius Ptolemy? Pseudo-Ptolemy? The Main Source of Moses Almosnino's Treatise on Astrolabe," *Journal for the History of Astronomy* 46, 343–350.

Sidoli, N., Berggren, J.L., 2007. "The Arabic version of Ptolemy's Planisphere or Flattening the Surface of the Sphere: Text, Translation, Commentary," *SCIAMVS* 8, 37–139.

Sidoli, Nathan, Saito, Ken, 2012. "Comparative Analysis in Greek Geometry," *Historia Mathematica* 39-1, 1-33.

Sierro Malmierca, F., 1990. *Judíos, moriscos e Inquisición en Ciudad Rodrigo*, Salamanca.

Silberberg, M., 1895. *Sefer ha-Mispar—Das Buch der Zahl, ein hebräisch-arithmetisches Werk des R. Abraham Ibn Esra*, Frankfurt am Main.

Smith, A.M., 1996. *Ptolemy's Theory of Visual Perception: An English Translation of the Optics*, Philadelphia.

Soncino, Joshua, 1731. *Naḥalah le-Yehošuʿa*, Constantinople.

Steinschneider, M., 1893. *Die hebräischen Übersetzungen des Mittelalters und die Juden als Dolmetscher*, Berlin.

Steinschneider, M., Goldberg, A., 1964. Mathematik bei den Juden, Hildesheim.

Toomer, G. J., 1968. "A Survey of the Toledan Tables," *Osiris* 15, 5–174.

Vajda, G., (n.d.). Manuscript notes about MSS 669–1213 Paris, Bibliothèque nationale (unpublished).

Varisco, D.M., 1997. *Medieval Folk Astronomy and Agriculture in Arabia and the Yemen*, Aldershot.

— 2000. "Islamic Folk Astronomy," in *Astronomy Across Cultures: The History of Non-Western Astronomy*, ed. Helaine Selin and Sun Xiaochun, Dordrecht, 615–650.

Ver Eecke, P., 1959. *Les sphériques de Théodose de Tripoli*, Paris.

Viladrich i Grau, M., 1986. *Kitāb fī al-ʿamal bi al-asṭurlāb (Llibre de l'us de l'astrolabi d'Ibn al-Samḥ)—Estudi i traducció*, Barcelona.

Wishnitzer, A., 2015. *Reading Clocks, Alla Turca—Time and Society in the Late Ottoman Empire*, Chicago.

Zonta, M., 2011. "Medieval Hebrew Translations of Philosophical and Scientific Texts: A Chronological Table," in *Science in Medieval Jewish Cultures*, ed. Gad Freudenthal, Cambridge, 17–73.

b. Online Resources

Paris BnF Catalogue online https://archivesetmanuscrits.bnf.fr/ark:/12148/cc76764.

David King, "Islamic Sacred Geography for Finding the Qibla by the Sun and Stars: A survey of the historical sources," available at https://muslimheritage.com/wp-content/uploads/1799/02/davidking-sacredgeography.pdf.

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