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The Alfonsine Tables in Hebrew*

Bernard R. Goldstein

Abstract

There are five copies of the Parisian Alfonsine Tables preserved in Hebrew, one from the fourteenth century and the others from the fifteenth century. By contrast, there are hundreds of extant copies in Latin, each with distinctive features. In one copy (now in Munich), Moses ben Abraham of Nîmes is specified as the translator of this text from Latin to Hebrew, and his work is dated AM 5220 (1459/60 CE). In the Munich copy, the canons (or instructions) as well as the tables are closely related to those in the *editio princeps*, published in 1483; indeed, no Latin manuscript dated prior to 1483 has been found that is as close to the print edition as this Hebrew version is. A brief summary of the contents of the five copies is included here, but their relationship to one another has not been determined. Nevertheless, it is clear that they are not all copies of the same translation.

Introduction

The Alfonsine Tables of Toledo were composed in Castilian by two Jewish astronomers, Isaac ben Sid and Judah ben Moses ha-Cohen, under the patronage of King Alfonso X of Castile (r. 1252–1284). Only the canons to these tables are extant; no copy of the tables themselves has survived.¹ These tables were conveyed to Paris, where they were recast into Latin in what are now called the Parisian Alfonsine Tables (henceforth PAT), which were widely diffused throughout Europe, beginning in the 1320s. The hundreds of copies of PAT differ from one another and there is no modern edition of them. So it is still useful to consult the *editio princeps*, edited by Erhard Ratdolt in 1483.²

The special characteristics of the standard version of these tables include the following: (1) the use of tropical coordinates instead of the sidereal coordinates used in the earlier Toledan Tables and derivatives of them; (2) the use of a combined model for precession with a periodic term for trepidation and a linear term for precession; (3) the use of sexagesimal days in the tables for mean motion, that is, multiples of the entry for 1 day from 1 to 60 (instead of dates in a calendar); (4) arcs measured in signs of 60° (instead of zodiacal signs of 30°); (5) a maximum solar equation of $2;10^\circ$ (instead of $1;59,10^\circ$ used in the Toledan Tables and elsewhere); (6) a maximum lunar equation of anomaly of $4;56^\circ$ (instead of $5;1^\circ$ used in the Toledan Tables and elsewhere); and (7) a maximum value of the equation of center of Jupiter of $5;57^\circ$ (instead of $5;15^\circ$ used in the Toledan Tables).³ All seven characteristics apply to the five copies in Hebrew.

I am aware of only a few references in Hebrew to the Alfonsine Tables before the fifteenth century (in addition to MS **V**: see below), despite the considerable number of sets of astronomical tables in Hebrew compiled in the fourteenth century.⁴ The first case occurs in Isaac

* This research has been undertaken within ALFA, a European Research Council project (Consolidator grant 2016 agreement no. 723085) funded for 2017-2022.

Israeli's *Yesod 'Olam* (1310), where eclipses observed by Isaac ben Sid are described.⁵ However, Isaac Israeli's tables do not depend on PAT.⁶ Another case is related to the Hebrew version of the "Tables of Paris" for 1368, an adaptation of the Oxford Tables for 1348 translated from Latin into Hebrew by Solomon ben Davin of Rodez (ca. 1370, southern France).⁷ These Oxford Tables were, in turn, based on PAT. The third reference occurs in the introduction to the tables of Judah ben Asher II (d. 1391), the great-grandson of the famous rabbi of Toledo, Asher ben Yeḥiel (d. 1328). In the canons to his set of tables, called *Huqqot šamayim*, Judah mentions the "zij" (the Arabic term for a set of astronomical tables) of King Alfonso, composed by Isaac ben Sid and his colleagues (Vatican, Biblioteca Apostolica, MS 384, 285b). However, Judah's tables do not seem to survive.⁸ It is surprising that more references in Hebrew to the Castilian Alfonsine Tables have not been found, given that the authors of these tables were prominent members of the Jewish community.

In the fifteenth century, the Parisian Alfonsine Tables were used in compiling the tables by Abraham Zacut of Salamanca (1452–1514) and by Moses Farissol Botarel of Avignon (late fifteenth century).⁹ Moreover, Mordechai Finzi (fl. 1475) adapted the Oxford Tables for Mantua.¹⁰ In the case of Zacut it is not known if he consulted a copy of these tables in Latin or in Hebrew, but Farissol Botarel presumably used the Hebrew translation, since he was a student of the translator, Moses of Nîmes (see §2 below).

1. Manuscripts of the Alfonsine Tables in Hebrew

There are five copies, all based on the Latin version produced in Paris:

1. **M**: Munich, Bayerische Staatsbibliothek, MS Heb. 126, 34b–114b [dated 1459/60]
2. **B**: Budapest, Hungarian Academy of Sciences, MS Heb. A518, pp. 4–184 [15th or 16th century]
3. **P**: St. Petersburg, Institute of Oriental Languages, Russian Academy of Sciences, MS Heb. C-76, 31a–54a [late 15th century]
4. **A**: Milan, Biblioteca Ambrosiana, MS Heb. X-193 Sup., 2a–27b [15th century]
5. **V**: Vatican, Biblioteca Apostolica, MS Heb. 381, 31a–69b [dated ca. 1375].

We also cite:

6. **U**: Vatican, Biblioteca Apostolica, MS Heb. 382, 31b–50a [15th century]
7. **R**: Ratdolt (ed.), *Alfontij regis castelle* [1483]

MS **M** is more extensive than the other copies in Hebrew and includes almost all the tables in the same order as those in the *editio princeps* of PAT, together with a brief introduction (4b–5a) by the translator, Moses ben Abraham of Nîmes, and some supplementary material.¹¹ Indeed, the two versions are so similar that it seems likely that Moses depended on a Latin manuscript very close to that which served as the archetype for the *editio princeps*. It is surprising that such a Latin manuscript was available in Provence some 23 years before the *editio princeps*. In fact, no known Latin manuscript of PAT dated before 1483 is as close to the print edition as is Moses' version. It is noteworthy that **M** includes the star catalog and the list of cities with their coordinates (as in **R**), both of which were probably added to PAT in the fifteenth century.

MS **B** is very similar to **M** in that it too has the star catalog and the list of cities with their coordinates. Moreover, there are marginal notes in **B** that begin "the translator said" that are also found in **M**. However, the technical terminology is often different (see §4 below) and the order of presentation is not the same.

MS **P** displays two lists of radices (i.e., initial positions), one for 1252 (the accession year of Alfonso X) and another for 1473, which is probably close to the date of this copy. Perhaps of interest is that the name for Mercury on fol. 52a is עטרעד, a corruption of the Arabic *Uṭārid*, although on fol. 53a (and elsewhere) its name is the usual כוכב. This version has only calendrical tables, a list of radices, mean motion tables, equations for the Sun, Moon, and planets, and a partial table for the equation of time. Another text in this manuscript in the same hand has been identified as the canons to the astronomical tables of Judah ben Verga of Lisbon (fl. 1455–1475).¹²

MS **A** is characterized by an unusual notation for entries in the tables: each sexagesimal digit is written in decimal place-value notation to be read from left to right, although the entry as a whole is to be read from right to left (as is customary in a Hebrew text). This notation is also used for the argument in the tables. Hence, for example, in this manuscript 35 is written הג instead of the usual לה, that is, the first nine letters of the Hebrew alphabet are used for 1,...,9, and zero is represented by a circle with a horizontal bar touching the top of the circle. This decimal place-value notation is found in a few other Hebrew astronomical manuscripts,¹³ but the combination with sexagesimal notation seems to be unique to **A**. The heading on **A** 28a, “From here on are [tables] according to the Prince [i.e., Abraham Bar Ḥiyya],” indicates that the Alfonsine Tables end on fol. 27b. This version of PAT has only a list of radices, mean motions, and equations for access and recess, the Sun, the Moon and the planets.

MS **V** has dated examples in the fourteenth century and refers to Cyprus; hence, it cannot depend on the translation by Moses of Nîmes made in the late fifteenth century.¹⁴ There are canons on fols. 19a–28a, and on fol. 21a (col. 1) we are told that a lunar eclipse took place in Cyprus on August 22, 1374, at 9;30h after noon, which is confirmed by modern computations (with a difference of perhaps 0;20h). Moreover, on fol. 19a the epoch of these tables is given as the beginning of March 1376.

2. Canons

The introduction by the translator, Moses ben Abraham of Nîmes, is extant in **M** (4a–b) and **U** (31b–32a), and includes the date of composition: AM 5220 (1459/60 CE). John of Saxony’s canons (dated 1327) precede PAT in **R** (a2r–b3v); the corresponding text in **M** (b–22a) preserves Moses’ Hebrew translation of John’s canons. These canons are also extant in **U** (31b–50a).¹⁵ **A** supplement in **M** (22b–32a), which is not in **U**, corresponds to **R**, b3v–b8v: in **M** it consists of 12 chapters of instructions and includes a passage in chapter 10 (fol. 30b) that is almost word-for-word equivalent to a passage in Ratdolt’s edition concerning the prime meridian for the coordinates of cities (**R**, m6r).¹⁶ On **M** 22a there is a note at the bottom of the page: “Here end the canons for using the tables of Alfonso, composed by Maestro Joannes Denikoro in the city of Paris. What follows is a supplement and a commentary for some of the tables that were added to those of Alfonso. I, the translator, composed it [read: them] for [their] necessity (*hekreh*) and utility.”¹⁷ In **R**, the corresponding passage (b3v) is: “Expliciunt canones et quod sequitur est additio.” In **M** (4b) and **U** (32a), the author is called Danikoro (**M**: דניקורו) or Denikoraw (**U**: מאישטרו יואנניש די ניקורו), whereas in **U** (50a) he is called Maestro Joannes de Nikoro (מאישטרו יואנניש די ניקורו). Evidently, Joannes Danikoro etc. are corrupt forms of Johannes de Danecowe, one of the names of John of Saxony.

MS **V**, fols. 19a–28a, preserves canons that are unrelated to those of John of Saxony; notably they include examples for Cyprus (see above, §1). **B**, **P**, and **A** do not include any canons. The dating of **M**, **V**, and **P** is based on internal data, whereas that of **B** and **A** was taken

from the catalogue of the National Library of Israel. The only copy to mention the name of a translator is **M**. The relation of these five copies to one another has not been determined: tentatively, it seems that **M**, **P**, **A**, and **V** are independent of one another and that **B** is related to **M**.

3. Contents of the tables

Below I present a partial table of contents to facilitate comparing the five versions and illustrating their differences.

i. Calendrical material: **R**, c1r–c7v; **M**, 34b–39a; **B**, pp. 4–13; **P**, 31a–32a; 38a; **A**, 2a; **V** 31a–b
 These tables generally follow those in **R**; but in **A** there is only one page of calendrical material (fol. 2a) where the epoch is the era of Creation. One would expect a table for converting dates in the Hebrew calendar to sexagesimal days counted from Creation; indeed, there is a table (with no heading) that has entries for 19-year cycles 273 and 274,¹⁸ followed by entries for years 1 to 19, which, in turn, are followed by entries for months 1 to 12 in an ordinary year and months 1 to 13 in an embolismic year (the year begins with the month of Tishri). However, we have been unable to make any sense of the numbers in this list, e.g., for 1 year (= 12 months) the entry is 0,40,1,22;54,5.

ii. Radices: **R**, c8r–d2v; **M**, 39b–42a; **B**, pp. 14–19; **P**, 32b; **A**, 2a; **V**, 33b
M and **B** agree with **R**. However, in **P** the radices are for both May 31, 1252 (Toledo) and for the beginning of 1473; in **V** the radices are for the Incarnation. **A** displays the radices for the era of Creation,¹⁹ together with the apogees at that time. On **M** 42a there is a marginal note “The translator said: This table and the two preceding tables, which are of the same kind, are not among the tables of Alfonso; rather, they were added because of their great utility.” The tables on **M** 41a–42a correspond to those on **R** d1v–d2v. There are two more paragraphs in **M** 42a that agree with those on **R** d2v; cf. **B**, p. 19.

iii. Mean motions: **R**, d4r–e2r; **M**, 43b–49b; **B**, pp. 22–34; **P**, 33a–37b; **A**, 2b–8a; **V**, 32a–b, 34a, 36a–b, 40a–43a
M, **B**, and **V** agree with **R**; in **P** and **A** some of these tables are missing. In each table, all five Hebrew manuscripts display multiples of the daily motion from 1 to 60. For the mean motion in anomaly of Venus, see Fig. 1.

Fig. 1. Munich, Bayerische Staatsbibliothek, MS Heb. 126, 49a: Table for the mean motion in anomaly of Venus

iv. Equations for the Sun, the Moon, and the planets: **R**, e2v–g5v; **M**, 50a–69a; **B**, pp. 35–73; **P**, 39a–41a, 42a–54a; **A**, 9a–27b; **V**, 34b–35b, 37a–39b, 43b–58a
 In all five manuscripts these tables agree with **R**. In **A** the entries in the tables agree (but for minor variants) with those in **R**; however, the arguments are arranged for signs of 30° rather than for signs of 60°. There is a marginal note in **B** (p. 73): “The translator said: Here end the tables of Alfonso, and what comes after this is a supplement added to make these tables complete so that no others are necessary, but for the true [positions] of the fixed stars which are entered at the end that belong to Alfonso.”

v. Hourly motion of the Sun and the Moon: **R**, g6r–g7r; **M**, 69b–70b; **B**, pp. 125–127; **V**, 58a; not in **P** or **A**

This table is found in **M** and **B**, with a minimum motion of the Sun of $0;2,23^\circ/\text{h}$ and a maximum of $0;2,33^\circ/\text{h}$. For the Moon, the minimum motion is $0;30,21^\circ/\text{h}$ and the maximum is $0;36,25^\circ/\text{h}$ (as in **R**), rather than the expected $0;36,4^\circ/\text{h}$.²⁰ There is a marginal note in **M** (69b): “The translator said: This table together with 8 others that come after it are not among [the tables of] Alfonso; rather, they were added [because] they are essential and useful”; cf. **B**, p. 125, where this marginal note is crossed out. While it was the common practice in the Middle Ages to add or delete some tables in a copy of a set of astronomical tables, it was usually done silently. **V** has a different table for the hourly motion of the Sun and Moon, which closely corresponds to a table in the *zij* of al-Khwārizmī with minor variants.²¹ There is no table for the hourly motion of the Sun and the Moon in **P** or **A**.

vi. Planetary latitudes: **R**, h1v; **M**, 73a; **B**, p. 76; **V**, 68b–69b; not in **P** or **A**

The table for planetary latitudes in **M** and **B** agrees with **R**. **P** and **A** do not include this table. **V** has a completely different table, with arguments from 1° to 90° at intervals of 1° . The entries are all different from those in **R**, and there is only one entry for each argument for each planet, e.g., arg. 90° : Saturn $5;0^\circ$; Jupiter $2;30^\circ$; Mars $3;45^\circ$; Venus $5;0^\circ$; Mercury $6;15^\circ$. The table in **V** previously appeared in the Toledan Tables.²²

vii. Star catalogue for 1251 complete years and 5 complete months of the Incarnation (i.e., May 31, 1252): **R**, h2r–i8v; **M**, 74a–91a; **B**, pp. 149–183; not in **P**, **A**, or **V**

This catalogue is found in **M** and **B** and agrees with **R**. There is a marginal note on **M** 91a: “The translator said: Here are completed [*nišlemu*] the 48 constellations of fixed stars, corrected for the time of King Alfonso. This is the end of the tables of Alfonso; praise be to God and [give] thanks to His name. What comes after this is a supplement, added to make these tables complete so that one has no need of any other [tables].”

viii. Right ascension and equation of time: **R**, k1r–k2r, **M**, 91b–82b, **B**, pp. 78–80, **P**, 41b, **V** 65a–b; not in **A**

This table, which uses signs of 30° , is found in **M**, **B**, and **V**, and agrees with the corresponding table in **R**. **P** has entries for Capricorn to Leo only.

ix. List of cities and their coordinates: **R**, m5r–m6r; **M**, 114a–b; **B**, pp. 144–145; not in **P**, **A**, or **V**

This table is found in **M** and **B** and agrees with **R**. There is a marginal note on **M** 114b: “The translator said: Here end the tables of King Alfonso together with the supplements added by Christians to make them perfect [*šelemim*] so that an astronomer has no need of any other tables. I also added a few tables for oblique ascension for latitudes 40° , 41° , and 42° for, in my view, they are essential for anyone who seeks precision and perfection. May He who grants perfection to His creatures be praised and exalted forever.”

x. Declination table: **M**, 115b; **B**, p. 147; **V**, 64a; not in **R**, **P**, or **A**

It is unusual to find a declination table in a copy of PAT; indeed, this is an example of supplementary material added in the Hebrew versions of PAT. The arguments in this table in **M** and **B** use signs of 30° ; the maximum declination (the obliquity of the ecliptic) is $23;33,8^\circ$. The entries in this declination table correspond to those in the table by Levi ben Gershom, where the obliquity is also $23;33,8^\circ$. The same value for the obliquity appears in a declination table

ascribed to Abraham Ibn Ezra, but the entries in **M** and **B** are closer to those of Levi than to those of Abraham.²³ In any event, the table in **M** and **B** depends on Hebrew sources rather than on Latin. However, in **V** the declination table has a maximum of $23;33,30^\circ$, which is its value in the Toledan Tables.²⁴ As in the Toledan Tables, the argument in **V** is given at intervals of 1° from 1° to 90° .

4. Terminology

The terminology is not consistent from one copy of PAT in Hebrew to another, even in the case of **M** and **B**, which are otherwise closely related. Here are some examples:

1. Mean motion of the Sun

- M** תנועת חמה ונוגה וכתב האמצעית
- B** לוח אמצע השמש
- P** לוח אמצע חמה
- A** לוח ממהלך אמצעי של השמש
- V** לוח אמצע חמה

2. Solar equation

- M** לוח תיקון חמה
- B** לוח שווי השמש
- P** לוח תיקון חמה
- A** לוח מתיקון מקום השמש האמיתי
- V** לוח תיקון חמה

3. Mean motion in anomaly of Venus

- M** לוח תנועת חק נוגה האמצעית
- B** לוח תנועת חק נוגה
- P** לוח אמצע מנת נוגה
- A** לוח ממהלך אמצעי של מסלול נוגה
- V** לוח חק נוגה

4. Argument (equation of Saturn)

- M** טורי המספר המשותף
- B** קוי המספר
- P** טור מספר
- A** שורות המנין
- V** טורי המספר

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Notes

¹ José Chabás and Bernard R. Goldstein, *The Alfonsine Tables of Toledo*. Archimedes: New Studies in the History and Philosophy of Science and Technology, 8 (Dordrecht: Kluwer, 2003).

² Erhard Ratdolt, ed., *Alfontij regis castelle illustrissimi celestium motuum tabule* (Venice: Ratdolt, 1483).

³ Fritz S. Pedersen, *The Toledan Tables: A Review of the Manuscripts and the Textual Versions with an Edition* (Copenhagen: The Royal Danish Academy of Sciences and Letters, 2002).

- ⁴ Examples of Hebrew astronomical tables compiled in the fourteenth century can be found in Bernard R. Goldstein, *The Astronomical Tables of Levi ben Gerson* (New Haven: Connecticut Academy of Arts and Sciences, 1974); José Chabás, “The Astronomical Tables of Jacob ben David Bonjorn,” *Archive for History of Exact Sciences* 42 (1991): 279–314; and Bernard R. Goldstein and José Chabás, “Analysis of the Astronomical Tables for 1340 compiled by Immanuel ben Jacob Bonfils,” *Archive for History of Exact Sciences* 71 (2017): 71–108.
- ⁵ Chabás and Goldstein, *The Alfonsine Tables of Toledo*, pp. 140–141.
- ⁶ Bernard R. Goldstein and José Chabás, “The Astronomical Tables of Isaac ben Joseph Israeli of Toledo,” *Aleph* 17 (2017): 357–370.
- ⁷ José Chabás and Bernard R. Goldstein, “Adaptations of the Oxford Tables to Paris, Mantua, and Louvain,” *Journal for the History of Astronomy* 49 (2018): 99–115.
- ⁸ For a description of this manuscript, see Benjamin Richler et al., *Hebrew Manuscripts in the Vatican Library: Catalogue* (Vatican: Biblioteca Apostolica, 2008), pp. 327–330. A careful inspection of the manuscript leads me to doubt that the tables in this manuscript are associated with the canons by Judah ben Asher II. See Bernard R. Goldstein and José Chabás, “Three Tables for the Daily Positions of the Moon in a Fifteenth-century Hebrew Manuscript,” *Aleph* 15 (2015): 319–341, on p. 320.
- ⁹ José Chabás and Bernard R. Goldstein, *Astronomy in the Iberian Peninsula: Abraham Zacut and the Transition from Manuscript to Print*. Transactions of the American Philosophical Society 90.2 (Philadelphia: American Philosophical Society, 2000). For the date of Zacut’s death, see Bernard R. Goldstein and José Chabás, “New Evidence on Abraham Zacut’s Astronomical Tables,” *Archive for History of Exact Sciences* 72 (2018): 21–62, on p. 21. See also Bernard R. Goldstein and José Chabás, “The Astronomical Tables of Moses Farissol Botarel,” *Suhayl* 15 (2016–2017): 29–65.
- ¹⁰ Chabás and Goldstein, “Adaptations of the Oxford Tables.” See also Y. Tzvi Langermann, “The Scientific Writings of Mordekhai Finzi,” *Italia* (1988): 7–44; repr. in idem, *The Jews and the Sciences in the Middle Ages* (Aldershot: Ashgate, 1999), Essay ix.
- ¹¹ Very little is known about Moses ben Abraham of Nîmes. In addition to his version of the Parisian Alfonsine Tables, he also composed a poem in which he indicated that he was living in Avignon in 5226 [= 1466 CE]; see Ernest Renan and Adolf Neubauer, *Les Écrivains juifs français du XIV^e siècle*. Histoire Littéraire de la France, vol. 31 (Paris: Imprimerie nationale, 1893), pp. 779–780.
- ¹² Bernard R. Goldstein, “The Astronomical Tables of Judah ben Verga,” *Suhayl* 2 (2001): 227–289, on p. 228. See also idem, “Preliminary Remarks on Judah ben Verga’s Contributions to Astronomy,” in Luís Saraiva and Henrique Leitão, eds., *The Practice of Mathematics in Portugal: Papers from the International Meeting held at Óbidos [Portugal], 16–18 November 2000* (Coimbra: Coimbra University Press, 2004), pp. 63–90, on p. 72.
- ¹³ See, e.g., Goldstein and Chabás, “Three tables for the daily positions,” pp. 330, 339–340.
- ¹⁴ The Parisian Alfonsine Tables were translated from Latin to Greek by Demetrios Chrysoloras in 1380, where apparently Cyprus served as “intermediary”: Anne Tihon, “Numeracy and Science,” in Elizabeth Jeffreys et al., eds., *The Oxford Handbook of Byzantine Studies* (Oxford: Oxford University Press, 2008), pp. 803–819, on p. 808. It is possible that there is some linkage between the two translations associated with Cyprus and that are nearly contemporaneous.

- ¹⁵Richler et al., *Hebrew Manuscripts*, p. 326. On John of Saxony, see Chabás and Goldstein, *The Alfonsine Tables of Toledo*, pp. 284–286.
- ¹⁶Bernard R. Goldstein, “Notes on Hebrew Lists of Geographical Coordinates of Cities,” *Aleph* 18 (2018): 265–271.
- ¹⁷In his Introduction (**M**, 4b), Moses says that he “composed three treatises together, that is, Danikoro’s commentary, the Alfonsine Tables, and the tables of Sant Archangel (שאנט (ארקאנגיל”): cf. **U**, 32a. In **M** (4a) the name is given as Maestro Yoannes of Sant Archangel (מא' יואניש דשאנט ארקאנגיל): cf. **U**, 31b. I am informed by José Chabás that Milan, Biblioteca Ambrosiana, MS D 28 Inf., uniquely preserves a text by Johannes de Sancto Arcangelo (86r–97r): canons to PAT, beginning *Augibus planetarum ad eram Christi...*
- ¹⁸Cycle 274 began in AM 5188 (= $19 \times 273 + 1$), or 1427 CE.
- ¹⁹The heading is: “Mean positions of the planets and their anomalies for noon preceding the conjunction of *tohu*,” where “the conjunction of *tohu*” refers to the first conjunction of the Sun and Moon in Tishri of the first year of Creation. See Eduard Mahler, *Handbuch des jüdischen Chronologie* (Leipzig: G. Fock, 1916), p. 488.
- ²⁰Bernard R. Goldstein, “Solar and Lunar Velocities in the Alfonsine Tables,” *Historia Mathematica* 7 (1980): 134–140; idem, “Lunar Velocity in the Middle Ages: A Comparative Study,” in Josep Casulleras and Julio Samsó, eds., *From Baghdad to Barcelona: Studies in the Islamic Exact Sciences in Honour of Prof. Juan Vernet*, 2 vols. (Barcelona: Instituto Millás Vallicrosa, 1996), 1:181–194.
- ²¹See Heinrich Suter, *Die astronomischen Tafeln des Muḥammad ibn Mūsā al-Khwārizmī* (Copenhagen: The Royal Danish Academy of Sciences and Letters, 1914), pp. 175–180.
- ²²Pedersen, *Toledan Tables*, pp. 1319–1321.
- ²³Goldstein, *Astronomical Tables of Levi ben Gerson*, pp. 95–96 and 159.
- ²⁴Pedersen, *Toledan Tables*, p. 964.