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KEPLER AND HEBREW ASTRONOMICAL TABLES

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I have spent many years studying medieval Hebrew astronomical tables (or zijes) and, in the absence of early editions in Hebrew characters, it has not been easy to determine the extent to which 'mainstream' European astronomers in the sixteenth and seventeenth centuries were aware of them.[1] It was therefore of considerable interest to learn from Noel Swerdlow about a passage in the introduction to Kepler's Rudolfine Tables (1627):

> I have in part followed Jewish astronomers, whose tables in Hebrew character(s) I have seen, entering with six-degree (intervals) of the anomaly of the Moon, single-degree (intervals) of the elongation of the Moon from the Sun.[2]

As Swerdlow noted in his initial message to me, Kepler is clearly referring to a double argument table for the first and second inequalities of the Moon.

The question is, can the table that Kepler describes somewhat vaguely be identified with an extant manuscript to which Kepler might have had access? My first step was to locate double argument lunar tables in Hebrew manuscripts, and I found the following four items.

(1) Levi ben Gerson (Orange, France, d. 1344) composed a long treatise on astronomy in 136 chapters, including many tables that he computed (rather than copied). Among them is a double argument table for the Moon, where one argument is the lunar anomaly at intervals of 10° from 0° to 350°, and the other argument is the number of days since syzygy at intervals of 1 day from 1 to 14 (representing the lunar elongation from the Sun).[3]

(2) Judah ben Asher II (Burgos, Spain, d. 1391) compiled a zij that includes extensive double argument tables for the daily velocities of the Moon and the planets; they are the most extensive such tables in the period before 1500, as far as I know, in Hebrew, Arabic, or Latin. In the table for the Moon one argument is the anomaly from 2° to 360° at intervals of 2°, and the other argument is the double elongation at irregular intervals from 0° to 346° (0°, 14°, 28°, 43°, 52°, 60°, 73°, 97°, 129°, ..., 346°). This table survives uniquely in Vatican, MS Heb. 384, ff. 375a–384b.[4]

(3) Judah ben Verga (Lisbon, *fl.* 1455–80) composed a zij that includes a double argument lunar table where one argument is the lunar anomaly in days from 1 to 27, and the other argument is the elongation in days from 1 to 14. This table survives in two copies: Paris, MS Heb. 1085, f. 94b; Oxford, Bodleian Library, MS Poc. 368, f. 230b.[5]

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(4) The Oxford Tables of 1348, composed in Latin, probably by Batecomb, contain many double argument tables for the planets and the Moon.[6] In particular, the lunar equation table has two arguments: the anomaly from 6° to 360° at intervals of 6°, and the elongation from 3° to 360° at intervals of 3° (Oxford, Bodleian Library, MS Rawlinson D 1227, ff. 64v–65r). The canon for this table is:

> The mean elongation and argument having been found, the table of [the Moon] is entered with the elongation on the left hand side and its argument along the top of the table. At the crossing you will find its true elongation from the Sun in degrees, minutes and seconds, with the prescribed sign between the transverse lines. To this is added the mean motus of the Sun, which results from the addition of the aux of the Sun written in the table at its argument; and the true place of the Moon in the ninth sphere will result, for the time proposed. The proportional part is to be sought if necessary ... [two alternative methods are offered for determining this].[7]

(4a) The Oxford tables were translated into Hebrew by Solomon ben Davin de Rodez, a pupil of Immanuel ben Jacob Bonfils of Tarascon (*fl.* 1350), but the meridian of Oxford was replaced by the meridian of Paris, and the radix was changed from 1348 to 1368. The lunar equation table is preserved in two Hebrew manuscripts: Oxford, Bodleian Library, MS Reggio 14, ff. 63a–68b, and Munich, MS Heb. 343, ff. 114b–120a; it is entitled: "Table indicating the true elongation of the Moon from the mean position of the Sun, arranged for all places and times." The Hebrew version has the same structure as the table in Latin, the entries agree but for minor variants, and the canon is also very nearly the same.[8]

(4b) There was another Hebrew version of the Oxford Tables of 1348, produced by Mordecai Finzi (Mantua, *fl.* 1440–75). The lunar equation table is preserved uniquely in Oxford, Bodleian Library, MS Lyell 96, ff. 18b–25a, and its title is: "Table from which may be known the true elongation of the Moon from the mean motion of the Sun for all places and times."[9]

The tables listed in items (1), (2), and (3) do not have the structure that Kepler describes, whereas the tables in item (4) differ very little from his account: Kepler gives the intervals as 6° of anomaly and 1° of elongation, whereas the Oxford Tables have 6° in anomaly and 3° in elongation. So the fit is not exact. But perhaps Kepler depended on his memory, having seen the manuscript some years earlier.[10] Since the tables in item (4) are identical (but for copyist's errors), it cannot be decided immediately which manuscript Kepler saw. But in the following discussion, I will ignore item (4b) because it seems very probable that Kepler saw a manuscript of item (4a).

As noted above, there are two copies of the tables in item (4a). The Oxford manuscript is written in a North African hand probably from the mid-seventeenth century, and unlikely to have been in Europe at the time of Kepler.[11] But could Kepler have seen Munich, MS Heb. 343? According to Striedl, this manuscript

belonged to Widmanstetter (d. 1557) and, indeed, his signature appears on f. 1v.[12] Widmanstetter was an interesting Renaissance character: he served as secretary to Pope Clement VII (pontificate: 1523–34), and to Cardinal Nicolaus von Schönberg, among others. In fact, there is a well known story of Widmanstetter explaining the Copernican theory to the Pope in 1533, some ten years before the publication of *De revolutionibus*.[13] And Schönberg's letter to Copernicus in 1536, asking for more information and urging publication, was printed in the *editio princeps* of *De revolutionibus* (Nuremberg, 1543), just after the anonymous preface that was, in fact, written by Osiander.[14] Widmanstetter spent many years in Italy collecting manuscripts and in 1558, soon after his death, they were acquired by Albert V of Bavaria. Indeed, some 136 Hebrew manuscripts now in the Bavarian State Library had belonged to Widmanstetter, and of them 52 are predominantly scientific in content. MS 343 is itself a small 'library' of Hebrew zijes.[15]

The story of Kepler and Hebrew tables seems to begin with a passage in a letter that Herwart von Hohenburg wrote to Kepler, dated Munich, 24 September 1602:

> The *Tabulae resolutae Hebraicae* are by various authors as the enclosure [in the manuscript?] shows. I made an arrangement some time ago with the Archbishop of Salzburg who has taken them with him and, if he can find someone capable without sparing expenses, hopefully, he will get them translated, for he already has had them for a considerable time with him.[16]

From this letter we learn that Herwart von Hohenburg, the Chancellor of Bavaria and Kepler's patron, was interested in getting some Hebrew astronomical tables translated (possibly for subsequent publication), and had apparently lent the manuscript to the Archbishop of Salzburg for this purpose. (The rules for removing manuscripts from a library were certainly not as strict as they generally are today!)

As far as I can tell, Kepler did not respond to this part of Herwart's letter until April 1607: "Where are the Hebrew tables hidden, for which you had offered hope that they would be published by the Bishop of Salzburg."[17] Herwart's reply to Kepler came in a letter dated 10 Oct. 1607: "The Hebrew tables have not yet been translated."[18] Kepler then replied to Herwart in a letter dated 24 Nov. 1607: "From the Hebrew tables and the *Sphaera* of Abraham bar Ḥiyya I wish to prepare a catalogue of witnesses and observers concerning the length of the year and similar things."[19]

In this exchange, the expression *Tabulae hebraicae* is used (as in Kepler's introduction to the Rudolfine Tables), whereas in 1602 Herwart von Hohenburg has *Tabulae resolutae Hebraicae*.[20] Nevertheless, the reference to the Archbishop of Salzburg seems to connect the passages, and I think it safe to assume that the same manuscript underlies all the discussions.

At this point one would like to find 'the smoking gun', an explicit remark in Kepler's correspondence about seeing a Hebrew manuscript in Munich or, alternatively, that Herwart von Hohenburg had sent the manuscript to Kepler. But

there is no such evidence as far as I can tell. Part of the problem may be that the extant correspondence between Herwart von Hohenburg and Kepler ends in 1611 even though Herwart lived to 1622 and Kepler to 1630.[21] But in his book on comets (Augsburg, 1619), Kepler indicates that he had received from Herwart reports of observations made in Ingolstadt by an unnamed astronomer (presumably J. B. Cysat) of a comet that appeared in December 1618.[22] Further evidence for a continuing relationship until very nearly the end of Herwart von Hohenburg's life comes from a letter by J. B. Cysat (a Jesuit at Ingolstadt in Bavaria) to Kepler in Feb. 1621:

> Two days ago, immediately after you left for Ratisbon [Regensburg], the printer, Eder, gave me a letter, written on your behalf, to give to our Rector. It was from Herr Herwart about the *Ephemerides*, and was written last October. The gist of [Herwart's] letter was this: It seemed to him, to the other Counsellors of the Duke, and to the Rector of the College at Munich, that your *Ephemerides* could be published at Ingolstadt, since they contain nothing against the Catholic faith. Father Johann Lanz (in a letter to me) says that the Rector of the college and himself think that the *Ephemerides* could be published at Ingolstadt, especially if the name of the place and the printer are omitted. He added, furthermore, that he had heard from Herr Jocher, recently returned from his Grace, at Linz, that permission had been granted you to reside in Munich, for which reason your request should be more readily granted. Having read these two letters, the Rector and the Dean of Theology immediately granted the permission. Therefore, there is now nothing to prevent your *Ephemerides* being published at Ingolstadt.[23]

From September 1620 to November 1621 Kepler was away from Linz to help defend his mother against the charge of witchcraft. He left his family in Regensburg, and resided for part of the time in Ingolstadt.[24] Although there does not seem to be any direct evidence that Kepler saw Herwart in Munich, in the dedication to the *Epitome of Copernican astronomy*, Books 5, 6, and 7 (dated Frankfurt, July 1621), Kepler says that he spent some time in Munich in 1621.[25] Moreover, in his biography of Kepler, Frisch cites a passage where Kepler says that in April 1621 he was in Munich.[26] Soon thereafter, on 15 April 1621, Kepler was in Ulm, for he so dated the dedication of his "Astronomical Report on two lunar eclipses of 1620 and a solar eclipse of 1621" to Duke Johann Friedrich von Wuerttemberg; in this dedication Kepler indicates that his Ephemeris for 1621 has not yet been published.[27]

It seems likely that Kepler would have visited his old patron at that time when he was in Munich, and it would also have been possible for him to look briefly at a Hebrew manuscript in the library. Of course, there are other conceivable opportunities when Kepler might have seen this manuscript but, in the absence of further evidence, this seems the most likely.[28] Finally, it is perhaps ironic that Kepler's allusion to an astronomical table in Hebrew characters refers to a

text that had been translated from Latin, and not to a text composed by a Jewish astronomer as he seems to suggest.

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REFERENCES

1. At least 30 zijes in Hebrew (mostly unpublished) are known, but there has been no survey of them comparable to E. S. Kennedy, *A survey of Islamic astronomical tables* (*Transactions of the American Philosophical Society*, xlvi/2 (Philadelphia, 1956)). While some Hebrew zijes are translations from either Arabic or Latin, others were composed in Hebrew and may be considered 'original'. One might consider Abraham Zacut's tables to be an exception to the absence of early editions, for a Latin version of them was published in 1496 in Leiria, Portugal, but the Hebrew text was not printed at the time. See now J. Chabás and B. R. Goldstein, *Astronomy in the Iberian Peninsula: Abraham Zacut and the transition from manuscript to print* (*Transactions of the American Philosophical Society*, xc/2 (Philadelphia, 2000)). Some of these zijes are discussed in B. R. Goldstein, "The survival of Arabic astronomy in Hebrew", *Journal for the history of Arabic science*, iii (1979), 31–39; reprinted in *idem*, *Theory and observation in ancient and medieval astronomy* (London, 1985), Essay XXI.
2. J. Kepler, *Gesammelte Werke* [= *KGW*], ed. by M. Caspar *et al.* (20 vols, Munich, 1937–), x, 186: Secutus hac in parte sum Hebraeos Astronomos, quorum Tabulas Hebraico charctere vidi, incedentes per senos Anomaliae Lunae, singulas Elongationis Lunae à Sole gradus.
3. See B. R. Goldstein, *The astronomical table of Levi ben Gerson* (*Transactions of the Connecticut Academy of Arts and Sciences*, xlv (New Haven, 1974)).
4. B. R. Goldstein, "Abraham Zacut and the medieval Hebrew astronomical tradition", *Journal for the history of astronomy*, xxix (1998), 177–86, esp. pp. 179–81.
5. On Ben Verga, see Y. T. Langermann, "Science in the Jewish communities of the Iberian Peninsula", in *idem*, *The Jews and the sciences in the Middle Ages* (Aldershot, 1999), Essay I, esp. pp. 19–25.
6. J. D. North, "The Alfonsine Tables in England", in *Prismata*, ed. by Y. Maeyama and W. G. Salzer (Wiesbaden, 1977), 269–301, esp. pp. 279ff. A list of Latin manuscripts in Oxford with either text or tables appears on p. 299 n. 40. This essay was reprinted in *idem*, *Stars, minds and fate: Essays in ancient and medieval cosmology* (London and Ronceverte, 1989), 327–59, esp. pp. 337ff. and 357 n. 40.
7. The translation by J. D. North is based on Oxford, Bodleian Library, MS Bodley 432, f. 56v.
8. This canon is found in Munich, MS Heb. 343, f. 105r–v; and in Oxford, MS Reggio 14, at the bottom of ff. 57b–58b. See also Goldstein, "Survival" (ref. 1), 36.
9. On f. 3a there are a few inscriptions in both Latin and Hebrew characters that may yield some information on ownership, but they are not easy to read and I have not deciphered them. Langermann reports that there are notes in this manuscript in the hand of Finzi: see Y. T. Langermann, "The scientific writings of Mordekhai Finzi", *Italia*, vii (1988), 7–44, esp. pp. 26–28; reprinted in *idem*, *op. cit.* (ref. 5), Essay IX. However, the provenance of this manuscript before the twentieth century is unknown, according to a private communication from R. Judd (Bodleian Library, Oxford).

10. W. H. Donahue, who has just finished a translation of Kepler's *Optics: Paralipomena to Witelo & optical part of astronomy* (*Ad Vitellionem paralipomena, quibus astronomiae pars optica traditur*), informed me that Kepler often cites from memory, and that many of the quotations and citations in that work contain small discrepancies similar to the one noted here.
11. Privately communicated by B. Richler.
12. H. Striedl, "Geschichte der Hebraica-Sammlung der Bayerischen Staatsbibliothek", in *Orientalisches aus Münchener Bibliotheken und Sammlungen*, ed. by H. Franke (Wiesbaden, 1957), 1–37, esp. p. 7. For other examples of Widmanstetter's signature, "Joannis Alberti Widmestadij ...", see H. Striedl, "Die Bücherei des Orientalisten Johann Albrecht Widmanstetter", in *Serta monacensia*, ed. by H. J. Kissling and A. Schmaus (Leiden, 1952), 200–44, esp. plates IV and V.
13. S. Riezler, "Widmanstetter, Johann Albrecht", in *Allgemeine Deutsche Biographie* (56 vols, Leipzig, 1875–1912), xlii, 357–61, where the surname is given as Widmanstetter or Widmestadius, and the variant in the modern literature, "Widmanstadt", is explained as a back formation from the Latin. See also N. M. Swerdlow and O. Neugebauer, *Mathematical astronomy in Copernicus's De Revolutionibus* (New York and Berlin, 1984), 16–17; and W. J. Steiner, "Clement VII, Pope", in *The new Catholic encyclopedia* (19 vols, New York, 1967–79), iii, 931–2.
14. N. Copernicus, *De revolutionibus orbium coelestium* (Nuremberg, 1543), f. ij r; Copernicus alludes to this letter in his dedication to Pope Paul III (f. iij r).
15. M. Steinschneider, *Die hebraeischen Handschriften der k. Hof- und Staatsbibliothek in Muenchen* (Munich, 1895), 188–95.
16. *KGW* (ref. 2), xiv, 260: Die Tabulae resolutae Hebraicae seind diuersorum authorum wie die beylag zu erkhennen gibt. Unnd jch hab seidheero mitt jrer hochfürstlichen Gnaden dem herrn Ertzbischouen von Saltzburg dahin gehandlet, das Er die zu sich genomen, unnd da Er anderst yemand taugentlichen bekhomen khan, non parcendo sumptibus, uertieren lassen will, unnd versehenlich würdet, wie dan jre hochfürstliche Gnaden dieselben beraith ein geraume Zeitt bey sich haben. [Note that *uertieren* comes from the Latin *verto*, and means "to turn" or "to translate"; *versehenlich* is not recorded in dictionaries of modern German, but the verb, *versehen*, can have the meaning "to expect something to be prepared", from Old High German *farsehan* meaning *hoffend erwarten*: see, e.g., *Brockhaus Wahrig: Deutsches Wörterbuch*, ed. by G. Wahrig, *et al.* (6 vols, Wiesbaden and Stuttgart, 1980–84), vi, 537.] Seventeenth-century German can be very difficult to translate, and I have depended, in part, on advice from P. Dannhauer (Staatsbibliothek, Munich).
17. *KGW* (ref. 2), xv, 463: Ubi lateant Hebraicae tabulae, de quibus M. V. spem fecerat, fore ut à Salisburgensi Episcopo ederentur.
18. *KGW* (ref. 2), xvi, 61: Die Tabulae Hebraicae seind noch vnuertiert.
19. *KGW* (ref. 2), xvi, 80: Ex tabulis Hebraicis et Sphaera Abrahamj filij Chaja cupio instruere catalogum testium seu observatorum de anni longitudine et similibus. The book mentioned here is *Ṣurat ha-areṣ* by Abraham bar Ḥiyya (d. *c.* 1135) that appeared as *Sphaera mundi*, avtore rabbi Abrahamo hispano filio R. Haijae, Arithmetica secvndvm omnes species suas autore rabbi Elija Orientali, Qvos libros Osvvaldvs Schreckenfuchsius uertit in linguam latinam, Sebastianus uero Munsterus illustravit annotationibus (Basel, 1546); *cf. KGW* (ref. 2), xvi, 61. For a modern translation of the underlying Hebrew text, see J. M. Millás Vallicrosa, *La obra forma de la Tierra de R. Abraham Bar Ḥiyya ha-Bargeloni* (Madrid and Barcelona, 1956). In fact, Kepler would not have found anything useful to him in this elementary introduction to astronomy.
20. The meaning of "resolutae" as used by Herwart in his letter of 1602 is uncertain: there were tables known in Latin as *Tabulae Resolutae* that depended on the Alfonsine Tables but, as far as I know, they were never translated into Hebrew. See J. Dobrzycki, "The Tabulae Resolutae", in *De astronomia Alphonsi Regis*, ed. by M. Comes, R. Puig, and J. Samsó (Barcelona, 1987), 71–77; and E. Poulle and D. Savoie, "La survie de l'astronomie Alphonsine", *Journal for the history of astronomy*, xxix (1998), 201–7, esp. p. 202. In a private communication, N. Swerdlow suggested that "tabulae resolutae" here may just be a generic term for tables that use collected years, single years, months, etc. for mean motions, rather than the pure sexagesimal

structure of the Alfonsine Tables (*cf.* N. M. Swerdlow, "Regiomontanus on the critical problems of astronomy", in *Nature, experiment, and the sciences*, ed. by T. H. Levere and W. R. Shea (Dordrecht and London, 1990), 165–95, esp. p. 171).

21. See D. Albrecht, "Hans Georg Hörwarth [Herwart] v. Hohenburg", in *Neue Deutsche Biographie* (19 vols, Berlin, 1952–98), viii, 722–3.

22. *KGW* (ref. 2), viii, 187. See also p. 189: Diligensis quidam, vt ad me perscriptsit Herwartvs, ... In a note (p. 497), the editors of *KGW* indicate that Herwart's letter with these data has not been preserved. Cysat published his observations of a comet in 1618: J. B. Cysat, *Mathemata astronomica* (Ingolstadt, 1619) and, in an appendix to chap. 1 (pp. 10–11), Cysat says that he has seen Kepler's book (published earlier in 1619), that he is indeed the person referred to by Kepler as the observer in Ingolstadt, and he has no idea how Kepler received his observations. Also, J. Lanz (a Jesuit in Munich) wrote a letter to Cysat, dated Munich, 16 June 1619, in which he denies that Herwart received Cysat's observations from him (*KGW*, xvii, 358). I am most grateful to Peter Barker for examining the copy of Cysat's book in the library of the University of Oklahoma.

23. For the translation, see M. W. Burke-Gaffney, *Kepler and the Jesuits* (Milwaukee, 1944), 119; *KGW* (ref. 2), xviii, 63–64: Ante biduum, statim uidelicet postquam Dominatio Vestra hac Ratisponam transijt, tulit ad me literas Ederus Typographus, nomine Dominationis Vestrae Magnifico Domino Academiae nostrae Rectori trandendas. etant eae literae Magnifici Domini Herwardi in cause Ephemeridum Dominationis Vestrae huc iam Octobri mense perscriptae; tradidi eas ipsemet, una cum alijs quoque literis P. Joannis Lanzij eodem mense eadem super re ad me perscriptis. Literarum Domini Herwardi summa haec fuit: Sibi, Consiliarijs reliquis Serenissimi Principis, et R. P. Rectori Collegij Monachij uideri Ephemerides Dominationis Vestrae posse utique Ingolstadij in lucem edi cum nihil contra Catholicam fidem contineant. In suis uero literis P. Joannes Lanz ait etiam R. P. Rectorem Collegij et se sentire meras Ephemerides Dominationi Vestrae Ingolstadij imprimi posse, praesertim si nomem loci et Typographi omittantur. addit porro, se ex ore Magnifici Domini D. Jocheri qui Linzio à Serenissimo Principe potestatem esse factam Monachij habitandi; quare etiam ea de causa tantò lubentius esse petitioni Dominationis Vestrae annuendum. Vtrasque istas literas cum et Magnificus Dominus Academiae Rector, et Spectabilis D. Theologicae Facultis Decanus perlegissent (nam eas utrisque tradidi) statim Dominationi Vestrae licentiam concesserunt suas Ephemerides hic Ingolstadij imprimendi.

24. M. Caspar. *Kepler 1571–1630*, transl. by C. D. Hellman (New York, 1959), 262.

25. *KGW* (ref. 2), vii, 360: Monachii breue tempus constitutione antiquarum Epocharum et computatione Eclipsium intercessit.

26. Johannis Kepleri Astronomi *Opera omnia*, ed. by C. Frisch (8 vols, Frankfurt and Erlangen, 1858–71), viii, 880: 2. Aprili [1621] Monachii consideratio longitudinis anni sideri. Calculus eclipsium Babylonicarum, ad constitutionem antiquarum epocharum.

27. *KGW* (ref. 2), xi/1, 495.

28. To be sure, it is possible that there was some otherwise unknown Hebrew manuscript seen by Kepler, but that would take us into the realm of pure speculation. Also, since the location of the manuscript in item (4b) at the time of Kepler is unknown, there is the possibility that Kepler saw it, but I take it to be unlikely in light of the evidence concerning the manuscript in Munich.