The Astronomical Tables of Judah ben Verga

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Introduction

Judah ben Verga was active in Lisbon from about 1455 to 1475. A recent survey of his scientific works indicates that he wrote the following astronomical treatises, none of which has been published or translated: a commentary on al-Farghānī's *Elements of Astronomy* (presumably based on the Hebrew version by Jacob Anatoli); a work belonging to the genre of *hay'a* called *Zeh Sefer Toledot ha-Shamayim we-ha-Areṣ* (*This is the Book of the Generations of the Heavens and of the Earth:* cf. Gen. 2:4); a treatise on an instrument called *ha-Keli ha-Ofqi* (*The Horizontal Instrument*): Paris, Bibliothèque Nationale de France [BNF], MS Heb. 1031, ff. 155b-163a [Q]; and, of greatest interest for us, a zij. He recorded observations he made in Lisbon of an autumnal equinox in 1456 and of Regulus in 1457; he calculated a true conjunction of the Sun and Moon for 1474, and referred to a lunar eclipse to take place in the future on March 22, 1475, and a solar eclipse to take place on July 29, 1478. Ben Verga mentions the following Jewish predecessors: Judah ben Asher, Jacob ben David Bonjorn (also known as Jacob Poel), Levi ben Gerson,

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and Moses Narboni, all of whom lived in the fourteenth century; and Abraham Ibn Ezra who lived in the twelfth century. On the other hand, as far as I can tell, the only Muslim predecessors he mentions are al-Farghānī and Ibn al-Zarqālluh (Langermann 1999, pp. 19-25; Goldstein 2002).

The tables of Judah ben Verga are preserved in two Hebrew manuscripts: Paris, BNF, Heb. 1085, ff. 86b-98a [P]; and Oxford, Bodleian Library, MS Poc. 368 (= Nb. 2044), ff. 222b-236a [Ox]; and the canons in Hebrew are preserved uniquely in St. Petersburg, Russian Academy of Sciences, MS Heb. C-076, ff. 57a-65a [R]. Lisbon is frequently mentioned in the canons, but only once in a heading of the tables (see Table 21). Ben Verga's name does not appear in either the tables or the canons; there is no title for the tables, but a title is given in the canons: *Ḥuqot Shamayim (Ordinances of the Heavens:* R, f. 57a; cf. Job 38:33). The two copies of the tables are textually very close, for they share many errors in common (see, e.g., Table 23, Cnc col. 2; Table 24, col. 1). Few predecessors are mentioned in the canons, notably, Ptolemy, Azarquiel (MS: Azarqāl), and Ibn Ezra (R, 64a), and both Ptolemy and Azarquiel are mentioned in the tables (see Tables 12, 22, and 27).

The goal of this paper is to indicate some of the peculiarities of Ben Verga's tables, rather than to offer a complete edition of them. For this reason, only two of the planetary equation tables (Table 14 [Saturn], and Table 17 [Venus]) are excerpted here: the tables for the other superior planets have the same structure as the table for Saturn, and the table for Mercury as that for Venus. The author clearly intended the planetary equation tables to be 'user-friendly', for these double argument tables only require linear interpolation. But the decision to use the number of days as one argument (for the mean Sun for outer planets, and the mean anomaly for inner planets) introduces more inconvenience than it eliminates, for interpolation is not as easily accomplished as it would be with arguments at a fixed interval of a whole number of degrees. Double argument tables for the planetary equations have been found in Arabic, Latin, and Hebrew, but none has Ben Verga's arrangement for them (see North 1977, Chabás and Goldstein 2000, pp. 21-22; and an anonymous zij with radices for 1400 in Vatican, MS Heb. 384, ff. 263a-277a [V]).

The table for the lunar equation is also arranged with two arguments (Table 13), and the table for the solar equation (with only one argument) as well as the table for the time from mean to true syzygy (with two arguments) are presented in much the same way (Tables 11 and 22). The maximum solar equation, 1;53°, is in the tradition of Ibn al-Kammād (whose name is not mentioned), but the equations underlying the other planetary equation tables seem to be based on Ptolemy's models with his epicyclic radii and eccentricities (except for Venus where al-Battānī's eccentricities are used) together with Ben Verga's parameters for the mean motions. Table 21 for mean conjunctions is most unusual, but it has its own inner logic (see the commentary to that table).

Table A: Mean Motion Parameters

Planet	Ben Verga	Another Zij	Source
Saturn	0; 2, 0, 33, 26°/d	0; 2, 0, 33, 31°/d	*Almagest*, ix.4[1]
Jupiter	0; 4, 59, 14, 35	0; 4, 59, 14, 27	*Almagest*, ix.4[2]
Mars	0;31, 26, 37, 4	0;31, 26, 36, 54	Almagest, ix.4[3]
Sun	0;59, 8, 20, 12	0;59, 8, 20, 9	Levi ben Gerson[4]
Anom. of Venus	0;36, 59, 29, 44	0;36, 59, 29, 27	Toledan Tables[5]
Anom. of Mercury	3; 6, 24, 7, 7	3; 6, 24, 7, 0	*Almagest*, ix.4[6]
Moon	13;10, 35, 1, 9	13;10, 35, 1, 15	Alf. T. (1483)[7]
Lunar Anomaly	13; 3, 53, 57, 5	13; 3, 53, 55, 56	Levi ben Gerson[8]
Asc.Node	–0; 3, 10, 32, 34	–0; 3, 10, 38, 7	Alf. T. (1483)[9]

[1] Trans. Toomer 1984, p. 429.

[2] Trans. Toomer 1984, p. 432.

[3] Trans. Toomer 1984, p. 435.

[4] Goldstein 1974, p. 106.

[5] Toomer 1968, p. 44; for a discussion of the relationship between the parameter in the Toledan Tables and the corresponding parameter in the zij of al-Battānī, see the commentary to Table 9.

[6] Trans. Toomer 1984, p. 441.

[7] Ratdolt 1483, f. d5v (= Poulle 1984, p. 135).

[8] Goldstein 1974, p. 107.

[9] Ratdolt 1483, f. d7v (= Poulle 1984, p. 139). In this case, Ben Verga's parameter is in error, and the Alfonsine parameter is merely presented to illustrate this.

It is difficult to determine the exact relationship between Ben Verga's zij and other zijes compiled in the late Middle Ages. But it is clear that there is little or no relationship with the Parisian version of the Alfonsine Tables (*editio princeps*: Ratdolt 1483) that was widely used in the 14th and 15th centuries throughout Europe. Ben Verga's mean motion tables are based on parameters that are reasonably close to parameters in other zijes, but not in any noticeable pattern of dependence (see Table A). Moreover, the planetary equation tables are arranged in a consistent manner that differs from the arrangement in other zijes known to me. For purposes of comparing Ben Verga's tables with antecedent and contemporary astronomical traditions (mainly in the Iberian peninsula), I have consulted the tables in Ptolemy's *Almagest* and his *Handy Tables* (2nd century); the zij of al-Khwārizmī and of al-Battānī (ninth century); the *Almanach* of Azarquiel (eleventh century); the zij of Ibn al-Kammād and the Toledan Tables (twelfth century); the zij of Levi ben Gerson, the zij of Immanuel ben Jacob Bonfils, the zij of Jacob ben David Bonjorn, and the Tables of Barcelona (fourteenth century); the Parisian version of the Alfonsine Tables (Ratdolt 1483); and the zij of Abraham Zacut (printed in 1496). In addition to these relatively well known zijes that are described in the secondary literature, I have also consulted an anonymous zij in Hebrew preserved in MS V; and two fifteenth century zijes associated with Salamanca in the late fifteenth century: the *Tabule verificate* (Madrid, Biblioteca Nacional, MS 3385, ff. 104r-113r), that has tables similar to Tables 5 and 21; and the "Tables in Castilian" (Madrid, Biblioteca Nacional, MS 3385, ff. 139r-153r) that has a table similar to Table 23 (see Chabás and Goldstein 2000, pp. 23-47). There seems to be some connection between Ben Verga and the astronomers in Salamanca (including Zacut), but there is not enough evidence to be more specific.

It is possible that Ben Verga depended on a Portuguese astronomical tradition, but I am not aware of any set of astronomical tables compiled in Portugal prior to the time when Ben Verga compiled his tables (the 1470s, in all likelihood). As far as I know, Zacut is the only astronomer to allude to Ben Verga's zij, but he had little to say about the character of Ben Verga's work and there is no evidence for a personal relationship between them (Cantera 1931, pp. 111, 153, 156, 352). Ben Verga is also mentioned in the Latin dedication to an unnamed bishop in Abraham Zacut's *Almanach Perpetuum* (Leiria, 1496), f. 2r:

> Others, wishing to correct this deficiency [i.e., the complexity of the rules for finding planetary positions], calculated their own tables in more 'user-friendly' (lit. shorter) ways, and among them was the Jew Ben Verga. (*Alii volentes hunc defectum corigere tabulas suas sub breuioribus modis calculauerunt de quorum fuit abenuerga ebreus.*)

In fact, this dedication was borrowed, for the most part, almost word-for-word from Regiomontanus's dedication to his *Tabulae directionum* (Augsburg, 1490). To be sure, the sentence in which Ben Verga is mentioned was not taken from Regiomontanus but, in all likelihood, the entire dedication was introduced by the printer of the *Almanach Perpetuum* without consulting Zacut: see Chabás and Goldstein 2000, pp. 91-95; cf. Albuquerque 1988, p. 78.

As is generally the case in medieval zijes, the canons neither explain how the tables were computed, nor indicate how the parameters were determined. But there are some worked examples in the canons for using the tables, and they refer to dates in the 1470s. Details of the worked examples for true conjunction of the Sun and the Moon for February 1474 are given in the commentary to Tables 21 and 22. There is also an undated worked example for Saturn reported in the commentary to Table 14. The examples in the canons (MS R) conform with the tables that appear in quite different manuscripts (MSS Ox and P), assuring us that these canons were intended for the tables that we ascribe to Ben Verga.

The canons include derivations of two parameters that are needed to use the tables, although they were not used in computing them. In R, f. 63a, a parameter for precession, 1°/68y, was determined by comparing two observations of Regulus: one by Ptolemy in 132 A.D. (according to Ben Verga, but in 139 A.D. according to *Almagest* vii.2; trans. Toomer 1984, p. 328) when it was $32^1/_2$° from the summer solstice; and the other in 1456 A.D. when Ben Verga found Regulus to be at 52° from summer solstice. The difference is 19;30° in 1324 Julian years or 1° in about 68y (accurately 67;54y). Ben Verga also remarks that the difference between the eighth and ninth spheres (i.e., the total precession) in 1468 was about 13° (R, f. 57b). These values can be compared with Zacut's parameter of 1° in about 66 years for precession, and a difference between the eighth and ninth spheres in 1478 of 13;52° (Cantera 1931, pp. 300; for comparable Maghribī data, see Samsó 1998). For Ben Verga the difference in longitude for a given star in the interval between Ptolemy's observation and his own is 19;30°, whereas the total precession is about 13°, leaving a remainder of about 6;30°. For Zacut the difference in longitude for a given star in the 1341 years between Ptolemy's star catalogue (dated 137 A.D.) and 1478 is 20;30° (Cantera 1931, p. 193), whereas the total precession is 13;52°, leaving a remainder of 6;38°. But 6;38° is exactly the difference between corresponding longitudes in Ibn al-Kammād's star list and Ptolemy's star catalogue, where the epoch of Ibn al-Kammād's star list is either the Hijra (622 A.D.) or possibly some 40 years earlier (see Goldstein and Chabás 1996, pp. 324ff; Samsó 1994a, p. 22). It seems that the longitudes in Ibn al-Kammād's list were understood to be sidereally fixed, and the difference between the eighth and ninth spheres was computed with respect to that list. This convention was certainly followed by Zacut (Chabás and Goldstein 2000, pp. 145-150 [Table AP 45]), and Ben Verga seems to have accepted it as well.

Ben Verga was also concerned to derive a value for the tropical year based on two observations, and he explained his procedure as follows (R, f. 64a:2-8):

> Know: I observed (*ᶜiyyanti*) at Lisbon with the large instrument I had that was divided at intervals of 10 minutes [of arc], and I found that the autumnal equinox (*tequfat tishri*) of year [5]217 [A.M.] took place on Tuesday, the first day of *Sukkot*, 13 complete days of September having passed of the year 1456 according to the Christians, and another 7 hours [read: 5 hours?] after noon. I examined (*ḥaqarti*) another autumnal equinox that took place at the time of Ptolemy who observed it in Alexandria, as he wrote [in the *Almagest*]. I found that the time that had elapsed between the two equinoxes is 1324 years of 365 days and 320 days and 3 hours. Since the difference in longitude between Alexandria and Lisbon is 40° or $2^2/_3$ hours, it is appropriate to add this to the 3 hours and the sum is $5^2/_3$ hours. When I divided this time interval by the number of solar cycles, I arrived at a year length of about 365d 5;5,18,31h [with MS Q, read: 5;48,18,31h]. In this time the first moving [sphere, i.e., the daily rotation] moves in excess of complete revolutions by 87;4,38°.

Ptolemy reports an autumnal equinox that he observed on Sept. 25, 132 A.D., 2h after noon, in *Almagest* iii.7 (trans. Toomer 1984, p. 168). Therefore, the time of Ben Verga's observation should be only 5 hours in addition to the number of completed days (rather than 7 hours, as in the text) for, 5h − 2h = 3h, and this is the difference in the times after noon of the two observations as reported in the text. According to the text, the time interval between the two observations in days and hours, 1324 · 365d + 320d 5;40h, is to be divided by 1324y; but this yields a year length of 365d 5;48,17,35h (corresponding to an excess of revolution of 87;4,24°), a value that does not agree with the year length in the text of 365d 5;5,18,31h. But, if the year length is emended to 365d 5;48,18,31h, the excess of revolution is 87;4,38°, as in the text, and the daily mean solar motion is 0;59,8,20,1°/d (cf. Table 1, which is based on a daily mean solar motion of 0;59,8,20,12°/d ± 0;0,0,0,10°/d). To get the emended year length of 365d 5;48,18,31h, the interval between the two observations would have to be 1324 years of 365 days plus 320d plus about 6h (instead of 5;40h, as in the text) for, when this interval is divided by 1324y, the resulting year length is 365d 5;48,18,29h. On the other hand, the year length in the text without emendation, 365d 5;5,18,31h, corresponds to a daily mean solar motion of 0;59,8,37,25°/d which is a very poor value for this parameter.

Ben Verga here considers the difference in longitude between Alexandria and Lisbon to be 40°: according to Ibn al-Kammād (Madrid, Biblioteca Nacional, MS 10023, f. 54v) and the Tables of Barcelona (Millás 1962, p. 238), the longitude of Alexandria is 63;0°; according to Ben Verga the longitude of Lisbon is 22;54° (see Table 29, below), and this is also the value in Zacut's *Almanach Perpetuum* (1496), f. 168r. Hence, the difference in longitude is about 40°, as in the text. There is often some confusion in medieval lists of geographical longitudes because there were several conventions for the prime meridian that were not always properly distinguished. In particular, there was a "meridian of water" placed in the Atlantic Ocean, 17;30° west of the Canary Islands that served as another prime meridian (see Comes 1992-94). So, for example, in the Alfonsine Table (ed. 1483, f. m5r) the longitude of Lisbon is 5;0°, rather than 22;54° that we find here. Similarly, in Ben Verga's *ha-*

Keli ha-Ofqi (MS Q, f. 160a), the coordinates of Lisbon are given approximately as follows: 5° in longitude from the West, and 39° in latitude. On the "excess of revolution", see Kennedy 1956, p. 147: the amount of the excess of revolution is the product of 15° and the excess in hours over the 365 days in the year length, for 1h corresponds to 15°.

A comparison of mean motion parameters shows no clear pattern of dependence (see Table A). Ben Verga's daily mean motions have been derived in all cases from the entry in his tables for 28 Julian years; entries for multiples of 28 years offer no additional information. Since the accuracy of the entries is given to minutes of arc, the parameter for daily mean motion is only valid to about ±0;0,0,0,10°, for ±0;0,30°/(28 · 365;15) = ±0;0,0,0,10°. Comparison of the parameter derived from the entry in the text for 28 years is made with the mean motion parameter (here rounded to sexagesimal fourths) from another zij that comes closest to Ben Verga's values. For the lunar node, Ben Verga's parameter is clearly in error in the third sexagesimal place, but his value is textually secure.

Table B: Radices of the Mean Motions for Jan. 1, 1385

Planet	Ben Verga	Alf. Tables
Saturn	86;44°	86;55°
Jupiter	81;20	81;57
Mars	1; 6	1;25
Sun	289; 6	289;30
Anomaly of Venus	22;42	22;23
Anomaly of Mercury	187; 4	185;12
Moon	159;45	162;32
Lunar Anomaly	81; 9	72; 7
Asc. Node[1]	137;38	139;19

[1] In Ben Verga's table, the entry is 7s 12;22°, but this has to be subtracted from 360° in order to obtain the position of the lunar ascending node.

Table C: Radices of the Mean Motions for 1400, i.e., Jan. 1, 1401

Planet	I Ben Verga[1]	II Vat. Heb. 384[2]	III I – II
Saturn	9s 12;26°	9s 10;52°	1;34°
Jupiter	6s 27; 6	6s 26; 6	1; 0
Mars	6s 3;42	6s 1;51	1;51
Sun	9s 19; 6	9s 16;59	2; 7
Anomaly of Venus	0s 25;33	0s 25;40	–0; 7
Anomaly of Mercury	11s 12;11	11s 11;37	0;34
Moon	4s 1;56	3s 23;11	8;45
Lunar Anomaly	3s 22;55	3s 23; 6	–0;11
Asc. Node[3]	6s 8;29	[blank][4]	——

1. The entries in this column have been computed by taking the sum of the radix for 1384 and the entry for 16y in the appropriate table.
2. The canons to this zij do not specify the date corresponding to the radix; but, judging from the position of the Moon, it seems to be the last day of the year, i.e., Dec. 31, rather than the first day of the following year (as is the case for Ben Verga's zij). Hence, the entries in this column have been computed by taking the sum of the radix for 1400 plus the entry for 1 day in the appropriate table.
3. The entries in Ben Verga's table yield 5s 21;31°, but this has to be subtracted from 360° to obtain the longitude of the lunar ascending node.
4. The years 1400, 1428, etc. appear in a table for the lunar ascending node, but the space for an entry next to them is blank in all cases; in contrast, there are entries for single years, and months.

Ben Verga's values for the planetary apogees (indicated in the equation table of each planet) differ by 10° from those in the headings for the planetary equation tables in the anonymous zij preserved in MS V (see Table D, cols. II and III). The entries in col. IV appear in a separate list, explicitly for 1400, on f. 263b of that manuscript, and they yield the values for the apogees in col. III by rounding (more or less). The apogees listed in col. IV differ from those of Ibn al-Kammād for the Hijra (622 A.D.) by 2:47,54° for Jupiter Mars, and Mercury, but by 2;47,24° for

Saturn, the Sun, and Venus. Using the principle that the planetary apogees have a proper motion equal to that of the solar apogee at the rate of 1° in 279 Julian years, we find that in the 778 years from 622 A.D. to 1400 A.D. the accumulated motion amounts to about 2;47,24° (accurately, 2;47,19°): cf. Goldstein 1998, p. 184, n. 22; Chabás and Goldstein 1994, pp. 28, 33. This motion of the solar apogee was introduced by Ibn al-Zarqālluh (see Samsó 1994b, p. 7; Calvo 1998, p. 55), and applied to the planetary apogees by several Andalusian and Maghribī astronomers, perhaps including Ibn al-Zarqālluh whose relevant work unfortunately is lost (cf. Samsó and Millás 1998, pp. 265-270). The planetary apogees indicate a possible relationship between Ben Verga and the anonymous zij, but nothing more specific can be said at this time. Note that Ben Verga used an epoch of 1400 in his table for the mean elongation of the Sun from the lunar ascending node (table 5) and in his table for mean conjunctions (Table 21), whereas elsewhere he used 1384. It is most unusual for a zij to have two different epochs, and nothing is said about this peculiar feature in either the tables or the canons.

Table D: List of Apogees (in degrees)

I Planet	II Ben Verga	III Vat. 384	IV Vat. 384, f. 263b
Saturn	252	242 (f. 268a)	241;25,54
Jupiter	172	162 (f. 269b)	161; 8,54
Mars	133	123 (f. 271b)	122;28,54
Sun	90	80 (f. 266a)	79;32,45
Venus	90	80 (f. 273b)	79;32,45
Mercury	212	202 (f. 275a)	201; 8,54

It is surprising that the two manuscripts of the tables use different technical terms, for which I have no explanation:

Tables 2, 3, 13. Moon: *levana* P; *ha-yareaḥ* Ox.
Tables 4, 5. Node: *ha-teli* P; *ha-tannin* Ox.
Table 10. Mercury: *kotev* P; *kokhav* Ox.
Table 20. Node: *ha-tannin* P mg.
Table 21. Conjunction: *dibbuq* P; *molad* Ox.
Table 24. The Hebrew word here for "distance" is *orekh* which usually means "longitude", whereas the usual word for "distance" is *merḥaq*.
Table 25. diameter: *ha-alakhson* P; *ha-qoter* Ox.

Moreover, in Tables 19 and 20, *merḥav* means 'latitude', but in table 27 (Ox only) it means 'declination'. In the canons (see the passage, above) Ben Verga's technical term for 'observe' is *ᶜiyyen*; this usage is unusual, for elsewhere *ᶜiyyen* has the more general meaning of 'consider', 'reflect', or 'speculate'. The Hebrew verb most frequently used in an astronomical context for 'observe' is probably *ra'a* ('see'), although Levi ben Gerson used *hibbiṭ*

In the list of contents, below, tables that have not been transcribed are marked with an asterisk; Table 29 only reports the list of geographical coordinates in MS P with a few remarks on the corresponding lists in MS Ox. The order of the tables displayed here does not follow either of the extant copies. Note that, in the manuscripts, the Sun is treated as just another planet, coming between Mars and Venus.

List of Tables

	P	Ox
1. Mean motion of the Sun	90b	226b
2. Mean motion of the Moon	93b	229b
3. Mean motion in anomaly of the Moon	94a	230a
4. Mean motion of the lunar node	95a	231a
5. Mean elongation of the Sun from the lunar ascending node	95b	231b
6. Mean motion of Saturn	86b	223a
7. Mean motion of Jupiter	87b	224a
8. Mean motion of Mars	88b	225a
9. Mean motion in anomaly of Venus	91b	227b
10. Mean motion in anomaly of Mercury	92b	228b
11. Equation of the Sun	91a	227a
12. Equation of the Sun acc. to Ptolemy	—	226b
13. Equation of the Moon	94b	230b
14. Equation of Saturn	87a	223b
15. Equation of Jupiter*	88a	224b
16. Equation of Mars*	89b-90a	225b-226a
17. Equation of Venus	92a	228a
18. Equation of Mercury*	93a	229a
19. Latitudes of Venus and Mercury	98a	228b
20. Lunar latitude	94b	230b
21. Mean conjunction	96a	232a
22. Time from mean to true syzygy	96b	232b
23. Parallax	97a	233a
24. Eclipses	97a	233a
25. Digits of Eclipse	97a	233a
26. Length of daylight	97b	—
27. Declination	—	226b
28. Normed right ascension	—	233b
29. Geographical coordinates	96a	234a, 235a-235b
30. Calendrical tables*	—	222b, 234b, 236a

*Not included in the summary of the tables that follows.

Table 1: Mean Motion of the Sun

Heading: "Table for the Mean Motion of the Sun"

Radices		[Julian] Years	
1384	9s 19; 6°	1	11s 29;45°
1412	9 19;20 *a*	2	11 29;31
1440	9 19;34	3	11 29;17
1468	9 19;48	4	0 0; 2
1496	9 20; 2	...	
		27	11 29;29
		28	0 0;14

a. With P mg; 19;35 P; 19;34 Ox.

There are also entries for months (Jan. to Dec.), and days (1 to 30).

Table 2: Mean Motion of the Moon

Heading: "Table for the Mean [Motion of the] Moon"

Radices		[Julian] Years	
1384	5 s 9;45° *a*	1	4s 9;23°
1412	9 7; 1	2	8 18;45
1440	1 2; 0	3	0 28; 8
1468	4 26; 3	4	5 20;42
1496	8 21; 2 *b*	...	
		27	11 2;24
		28	3 24;59

a. The differences in this column are not always 3s 24;59°, as expected.
b. No entry in Ox.

There are also entries for months (Jan. to Dec.), and days (1 to 30).

P mg. adds: hourly motion 0;32,57,30°.

Table 3: Mean Motion in Anomaly of the Moon

Heading: “Table for the Motion of Lunar Anomaly”

Radices	
1384	2s 21; 9°
1412	4 16;46
1440	6 12;23 *a*
1468	8 8; 0 *b*
1496	10 3;37 *c*

a. 12;26 Ox.
b. 8;3 Ox.
c. 1s 3;4 Ox.

[Julian] Years	
1	2s 28;43°
2	5 27;25
3	8 26; 9
4	0 7;56
...	
27	10 23;49
28	1 25;37

There are also entries for months (Jan. to Dec.), and days (1 to 30).

Table 4: Mean Motion of the Lunar Node

Heading: “Table for the Mean Motion of the Node”

Radices	
1384	7s 12;22° *a*
1412	1 13;42
1440	7 15; 0
1468	1 16;18
1496	1 17;17 *b*

a. With P; missing in Ox. Read: 7s 12;24 (?).
b. With P; this entire row is missing in Ox.
Read: 7s 17;36 (?).

[Julian] Years	
1	0 s 19;19°
2	1 8;38
3	1 27;57 *a*
4	2 17;20
...	
27	5 11;56
28	6 1;18

a. With P; 27;56 Ox.

There are also entries for months (Jan. to Dec.), and days (1 to 30).

Table 5: Mean Elongation of the Sun from the Lunar Ascending Node

Heading: "Table for Finding the Motion of the Sun from the Node"

Radices

1400	3s	11;31°
1428	9	10; 3 *a*
1456	3	14;35
1484	9	16; 7
1512	3	17;39 *b*

a. Read: 13;3.
b. This row is entirely missing in Ox.

[Julian] years

1	0s	19; 4°
2	1	8; 9
3	1	27;14
4	2	17;24 *a*
...		
27	5	11;25
28	6	1;32

a. With P and Ox; but read: 2s 17;22 (the sum of the corresponding entries in Tables 1 and 4).

There are also entries for months (Jan. to Dec.), and days (1 to 30).

Table 6: Mean Motion of Saturn

Heading: "Table for the Mean Motion of Saturn"

Radices

1384	2s	26;44° *c*
1412	2	9;13 *d*
1440	1	21;40
1468 *a*	1	4;11
1496 *b*	0	16;40 *e*

a. 1496 Ox.
b. Missing in Ox.
c. 20;44 P.
d. 9;13 P; 15;13 Ox.
e. 17;40 P; 16;40 P mg.; 16;5 Ox.

[Julian] Years

1	0s	12;13°
2	0	24;27 *a*
3	1	6;40
4	1	18;56
...		
27	11	0;13
28	11	12;29

a. 24;26 Ox.

There are also entries for months (Jan. to Dec.), and days (1 to 30).

Table 7: Mean Motion of Jupiter

Heading: "Table for the Mean Motion of Jupiter"

Radices		
1384	2s	21;20° [a]
1412	7	1;26
1440	11	11;34 [b]
1468	3	21;40
1496	8	1;46 [c]

[Julian] Years		
1	1s	0;20°
2	2	0;41
3	3	1; 1
4 [a]	4	1;26
...		
27	3	9;40
28	4	10; 6

a. 26;44 Ox.
b. 11;32 P. (Note that 11;32 is consistent with the previous entry, whereas 11;34 is consistent with the following entry.)
c. 1;40 Ox.

a. P (in Hebrew characters above the "4"): *wisest* (i.e., bissextile); the same word appears above successive multiples of 4 years. There is nothing like this in Ox.

There are also entries for months (Jan. to Dec.), and days (1 to 30).

Table 8: Mean Motion of Mars

Heading: "Table for the Mean Motion of Mars"

Radices		
1384	0s	1; 6° [a]
1412	10	20;32
1440	9	10; 6
1468	7	29;40
1496	6	19;14

[Julian] Years		
1	6s	11;17°
2	0	22;34
3	7	3;51
4	1	15;39
...		
27	4	7;45 [a]
28	10	19;34 [b]

a. Despite the manuscripts, the entry here should be 0s 0;58°: see commentary.

a. 7;46 P.
b. 19;3 P.

There are also entries for months (Jan. to Dec.), and days (1 to 30).

Table 9: Mean Motion in Anomaly of Venus

Heading: "Table for the Mean Motion in Anomaly of Venus"

Radices	
1384	0s 22;42°
1412	6 27;55
1440	1 3; 8
1468	7 8;21
1996	1 13;34

[Julian] Years	
1	7 15; 2°
2	3 0; 3
3	10 15; 6
4	6 0;45
...	
27	10 19;34
28	6 5;13 *a*

a. 5;3 Ox.

There are also entries for months (Jan. to Dec.), and days (1 to 30).

Table 10: Mean Motion in Anomaly of Mercury

Heading: "Table for the Mean Motion in Anomaly of Mercury"

Radices	
1384	6 s 7; 4°
1412	9 9;17
1440	0 11;30
1468	3 13;43
1496	6 15;56

[Julian] Years	
1	1 s 23;57°
2	3 17;53
3	5 11;50
4	7 8;53
...	
27	1 5;10
28	3 2;13

There are also entries for months (Jan. to Dec.), and days (1 to 30).

Table 11. Equation of the Sun

Heading: [missing]

{The mean}[1]		Cnc	Leo	Vir	Lib	Sco	Sgr	
		{3[s]	4[s]	5[s]	6[s]	7[s]	8[s]}[2]	
{days [hours]		0d 0h	30d 13h	60d 20h	91d 7h	121d 17h	152 d 4h}[3]	
{[parts of 1080]			505H	950H	491H	920H	490H}[3]	
The center		0[s] 0	1[s] 0	2[s] 0	3[s] 0	4[s] 0	5[s] 0	
Days	Center							Days[4]
0	0[s] 0; 0[°]	0; 0	5; 5*	1;36	3;53*	4;14*	5;58*	30
1	0;59	0; 2	0;57	1;37	1;53	1;39	0;57 *e*	29
2	1;58	0; 4	0;58	1;38 *c*	1;53	1;38	0;55	28
...								
28	27;36	0;52*	1;33*	1;52	1;41	1; 1*	0; 4	3
29	28;35	0;53	1;35*	1;53*	1;41	1; 0*	0; 3*	2
30	29;34	0;55	1;36	1;53	1;40	0;59 *d*	0; 1*	1
The center		11[s] 0	10[s] 0	9[s] 0	8[s] 0	7[s] 0	6[s] 0	
[days, hours]		334d *a* 19h	304d 8h	273d 22h	243d 11h	213d 1h	182d 14h	
{parts of 1080		273H *b*	930H	405H	960H	435H	990H}[5]	
The mean		Gem	Tau	Ari	Psc	Aqu	Cap	
{		2[s]	1[s]	0[s]	11[s]	10[s]	9[s]}[6]	

Ox mg. adds: "4 complete years, 2,26,30". Perhaps the numbers are to read as 0;2,27,30°/h for an approximation of the mean solar motion (= 0;59°/24h), emending the 26 to 27. Cf. Table 2 (P mg.) for a crude value for the hourly motion of the Moon.

1. With P; om. Ox.
2. With P; om Ox.
3. With Ox; om. P. Note that H stands for *ḥelaqim* of which there are 1080 in an hour. (There is no symbol in the manuscripts corresponding to 'H'.)
4. "Days" P; om Ox. There is another column for the argument of center corresponding to days 30 to 0. The entry for 30d is 12s 0;0°; for 29d it is 0s 29;1°; ....
5. With P; illegible in Ox, except for "parts of 1080 of an hour".
6. With P; om Ox.

Variants from Ibn al-Kammād's Solar Equation Table (Chabás and Goldstein 1994, pp. 6-10) are labeled: K.

a. With Ox; 338 P.
b. With P; 300 Ox.
c. With P; 1;35 Ox; 1;37;59 K.
d. With Ox; 1;59 P; 0;59,19 K.
e. With Ox; 0;54 P; 0;57,21 K.

The following variants refer to entries where K differs from the common reading of both MSS. In some cases, it is clear that both MSS are faulty.

*0s 28: 0; 50, 27 K.
*1s 0: 0; 54, 48 K. The text should read: 0;55.
*1s 28: 1; 33, 54 K.
*1s 29: 1; 34, 7 K.
*2s 29: 1; 52, 29 K (recomp. 1;52,35).
*3s 0: 1; 52, 40 K. The text should read: 1;53.
*4s 0: 1; 39, 52 K. The text should read: 1;40.
*4s 28: 1; 3, 27 K (recomp. 1; 1,26).
*4s 29: 1; 1, 10 K (recomp. 0;59,43).
*5s 0: 0; 59, 19 K. The text should read: 0;58.
*5s 29: 0; 2, 2 K.
*5s 30: 0; 0, 0 K.

Table 12: The Equation of the Sun According to Ptolemy

Heading: "The correction of the Sun according to Ptolemy, and it begins with 0;14, and at 180 it is 0;0."

Mg adds: "This correction for the Sun according to Ptolemy is the correction that is appropriate for the Sun according to its distance from apogee to perigee; after it [passes] the perigee of the Sun, [it enters] the other half from perigee to apogee."

Argument	[Correction]
6	0; 14[°]
12	0; 28
18	0; 42
...	
90	2; 23
93	2; 23
96	2; 23
99	2; 22
...	
177	0; 8
180	0; 0

Table 13. Equation of the Moon

Heading: “Lunar Correction Table”

Days	0	1	2	...	14
Mean	0s 0; 0°	0s 13; 11° *b*	0s 26; 21°	...	6s 4; 28°
Elong.	0s 0; 0°	0s 12; 11°	0s 24; 23°	...	5s 20; 40°
Corr.	0; 0°	3; 31°	7; 7°	...	2; 45°
Min. of Prop.	0	2	8	...	1

Days	Anom.					
0	0s 0; 0°	0; 0°	–0;18°	–0;30°(!)	...	0;13°
[0	0s 0; 0	0; 0	–0;17,31	–0;36,18	...	0;13,20]*
1	0 12; 4 *a*	–1; 2	–1;20	–1;42	...	–0; 5 (!)
[1	0 13; 4	–1; 2,39	–1;20,48	–1;42, 5	...	–0;50,10]*
2	0 26; 8	–2; 3	–2;21	–2;44	...	–1;51
[2	0 26; 8	–2; 2,47	–2;20,50	–2;43,48	...	–1;51,39]*
...						
7	3 1;27	–5; 1	–5; 6	–5;21	...	–5; 2
[7	3 1;27	–5; 0,36	–5; 6,51	–5;23, 0	...	–5; 2,39]*
...						
26	11 9;41	1;36	1;21	1; 7	...	1;56 (!)
[26	11 9;41	1;36,28	1;21,19	1; 7,51	...	1;50, 3]*
27	11 24;45 (!)	0;34	0;18	0; 1	...	0;48
[27	11 22;45	0;34,54	0;18, 3	0; 0,58	...	0;48,28]*

a. Read: 13;4.
b. With Ox; 13;12 P.

*[...] = recomputed.

(!) indicates poor agreement between the text and the recomputed values.

Table 14. Equation of Saturn

Heading: “Correction Table for Saturn”[1]

Days	*a*	895;3 *b*	1791;41*e*	...	5375;1 *h*
Mean	8s 12°	9s 12°	10s 12°	...	2s 12°
Center	0s 0°	1s 0°	2s 0°	...	6s 0°
Corr. of Center	0; 0°	3; 6°	5; 29°	...	0; 0°
Min. of Prop.	far 60	52	35	...	60 near
Min. of Lat.	38;24	56;50 *c*	56; 59 *f*	...	38; 24 *i*

Days	Mean Sun					
0	8s 12; 0°	0; 0°	–5;34°	–10; 4°	...	0; 0°
[0	8s 12; 0	0; 0	–5;33,13	–10; 5,27	...	0; 0]*
14	8 28;48 (!)	1;18	–4;19	–9; 5	...	–1;48
[14	8 25;48	1;16,25	–4;19,25	–9; 6,50	...	–1;45,59]*
28	9 9;36	2;30	–3; 2	–7;59	...	–3;44 (!)
[28	9 9;36	2;29,33	–3; 2,29	–7;58,22	...	–3;23,27]
...						
364	8 10;48	–0; 7	–5;39	– 1;11 (!)	...	0;10
[364	8 10;47	–0; 6,50	–5;39,30	–10;10, 4	...	0; 9,32]*
365	8 12; 0 (!)	0; 0	–5;34	–10; 4	...	0; 0
[365	8 11;46	–0; 1,20	–5;34,27	–10; 6,21	...	0; 1,52]*

Min. of Lat.	38;24*i*	56;50	56;59	...	38;24*i*
The center	0[s] 0°	11[s] 0°	10[s] 0°	...	6[s] 0°
Mean planet	8[s] 12°	7[s] 12°	6[s] 12°	...	2[s] 12°
Days	10750	9854;11	8958;21*g*	...	5375
Retr. Boundaries	67;18°	67; 7° *d*	66;40°	...	64;29° *j*
[Stations	67;15	67; 6	66;38	...	64;31]#

1. With Ox; om. P. Two columns that belong at the extreme right have not been displayed. They indicate days (counting up from 0 to 365) and the associated mean motion of the Sun (counting up from 8s 12;0° to 8s 12;0°), to be used with the column headings at the bottom of the table, on analogy with the two columns of argument at the left that are to be used with the column headings at the top of the table (see Table 17). To accommodate the arguments on the right, the entries for 365d (on the left) were computed for Saturn's apogee (8s 12;0°), rather than for 365 times the daily mean motion of the Sun added to the apogee (8s 11;46°).

a. The entries in this row in P are shifted one place to the left, e.g., 895 is in the first cell of this row, whereas it should be in the second cell, as it is in Ox.
b. With Ox; 895 P. Read 895;50.
c. 13;30 Ox.
d. 66;7 Ox.
e. 1791 P.
f. 14;52 Ox.
g. 8892;21 P.
h. 5375 P.
i. 31;24 Ox.
j. 64;23 P.

*[...] = recomputed.

#Computed from *Almagest,* xii.8.

(!) indicates poor agreement between the text and the recomputed values.

There is a small table for latitude below the main table:

Corr. Anom.	Latitude Northern	 Southern
0[s] 0;0°	2;3°	2;1°
6[s] 0;0°	3;2	3;5

Table 17. Equation of Venus

Heading: “Correction Table for Venus”

Days		0d	30; 4d(*c*)	...	182;15d(*e*)		
Mean		3s 0°	4s 0°	...	9s 0°		
Center		0s 0°	1s 0°	...	6s 0°		
Corr. of Center		0; 0°	0;53°	...	0; 0°		
Min. of Prop.		far 60	52	...	60 near		
Days	Anomaly					Days	Anomaly
0d	0s 0; 0°	0; 0°	–0;30°	...	0; 0°	584d	0s 0; 0°
[0	0 0; 0	0; 0	–0;29,33	...	0; 0]*		
60	1 7; 0	15;13	14;41	...	15; 35	524	10 23; 0 *a*
[60	1 6;59,30	15; 10,49	14;42, 1	...	15; 34,4]*		
...							
524	10 29; 0(*a*)	–15;13	–15;44	...	–15; 35	60	1 7; 0
[524	10 23; 3,36	–15; 9,34	–15;41,11	...	–15; 32,47]*		
584	0 0; 0	0; 6(!)	–0;30(*d*)	...	0; 0	0	0 0; 0
[584	0 0; 3, 5	0; 1,17	–0;28,17	...	0; 1,19]*		
Center		0s 0	11s 0	...	6s 0		
Mean		3s 0	2s 0	...	9s 0		
Limit of Retrogr.(*b*)		14; 11°	14; 0°	...	11; 39°		

a. The entry on the left reads 10s 29;0°, but the corresponding entry on the right reads 10s 23;0° (with P; 10s 23;6° Ox), as it should.
b. “Corrected anomaly” P.
c. 30 Ox. Note that 30°/(0;59,8°/d) = 30;26d.
d. 0;3 P.
e. This entry should be half of a year, but twice 182;15d is only 364;30d.

*[...] = recomputed.

(!) indicates poor agreement between the text and the recomputed values.

Table 19: Latitudes of Venus and Mercury

Heading: "Table of the inclination in latitude for Venus and Mercury"

Corrected Center and Anomaly	0s 0 12s 0	1s 0 11s 0	2s 0 10s 0	3s 0 9s 0	... ...	6s 0 6s 0
Minutes of prop. in inclination (*neṭiya*)	0	30	52	60	...	0
Minutes of prop. in slant (*neliza*)	60	22[a]	30	0	...	60
Inclin. of Venus	1; 2	0;27[b]	0;37[c]	0; 0	...	6;22
Slant of Venus	0; 0	0;41	1;20	1;27[d]	...	0; 0
Inclin. of Mercury	1;45	1;36	0;29[e]	0; 0	...	4; 5
Slant of Mercury	0; 0	0;55	1;44	2;20	...	0; 0

a. 52 *Alm.*
b. 0;57 *Alm.*
c. faint in Ox; 0;35 *Alm.*
d. 1;57 *Alm.*
e. 0;59 *Alm.*

Table 20. Lunar latitude

Heading: “Table of the latitude (*merḥav*) of the Moon”

[Arg.]	[lat.]
0°	0; 0°
10	0;52
20	1;42 *a*
30	2;29
40	3;13
50	3;50
60	4;20
70	4;42
80	4;55
90	5; 0

a. 1;42 P (as in al-Battānī); 1;49 Ox.

P mg. adds: “The latitude is from the node; from the ascending to the descending it is northern, and from the descending to the ascending it is southern.”

P adds (9 lines): “To find the latitude of the Moon, know the distance of its true position from the ascending node or from the descending node that you found....”

Table 21: Mean Conjunction

Heading: "Table for the days of conjunctions and the days of the distance of the Sun from its apogee; and the days of the moon from the apogee of its epicycle, constructed for Lisbon whose longitude is 23°"(*a*)

Subtable 1:

Radices	days of conjunction	days of the Sun(*c*)	days of the Moon
1400	16d 1;12h	201d 22;24h	8d 15;24h
1428	25 11; 9	201 18;36	12 21;24
1456	5 8;22	201 14;48	17 3;24
1484	14 18;19	201 11; 0	21 9;24
1512	24 4;16(*b*)	201 7;12	25 15;24

a. The heading in P is only partially preserved: "from its apogee (*govah romo*) whose longitude is 23°"

b. 24d 28;16h P and Ox. Ben Verga added 14d 18;19h (for 1484) and 9d 9;57h (for 28 years), and found 23d 28;16h (for 1512). He then added 1d to the 23d, but neglected to subtract 24h from the 28;16h.

c. P has 21d, instead of 201d, in all cases.

Subtable 2:

[Julian] years	days of the Sun	days of conjunction	days of the Moon
1	365d 0; 0h	10d 15;12h	6d 18;58h
2	364 18;11	21 6;23	13 13;56
3	364 12;21	2 8;50	20 8;55
4	0 0;43	14 0; 1	0 14;31
...			
27	364 16;39	27 7;29	24 0;24
28	0 5; 0	9 9;57	4 6; 0

Subtable 3:

Month	days of the Sun	days of conjunction	days of the Moon
January	31	1d 11;16h	3d 10;37h
February	59	29 11;16	3 21;23 [c]
March	90	1 9;48	7 8; 4
April	120	1 21;34 [a]	9 18;46
May	151	3 8;20	13 5;27
June	181	3 19;36	15 16; 8
July	212	5 6;52	19 2;50
August	243	6 18; 8	22 13;19 [d]
September	273	7 5;24	25 0;12
October	304	8 16;40	0 21;35
November	334	9 3;56	3 8;17
December	365	1 15;12 [b]	6 18;58 [e]

a. Read 21; 4 (as in Madrid, MS 3385, f. 104r).
b. Read 10d 15;12h; see the entry for 1 year.
c. 21;28 Ox.
d. Read 13;31.
e. 16d 18;58 P; see the entry for 1 year.

Subtable 4:

	The Moon and the Conj.		Cycles of the Moon	
cycle 1	29[d]	12;44,3,21[h][a]	27[d]	13;18[h][b]
cycle 2	59	1;28	55	2;37
cycle 3	88	14;12	82	15;56
half-cycle conj.	14[d]	18;22,1,40[h]		

a. 12;44,2,40[h] P; 12;3,21[h] Ox. It seems that the copyist of Ox omitted the 44 minutes, for 29d 12;44,3,20h = 29;31,50,8,20d which is the value for the mean synodic month in the *Almagest*.
b. This is the length of the anomalistic month. In Table 3, the lunar motion in anomaly is 13;3,53,57,5°/d, corresponding to an anomalistic month of 27d

13;18,34h. Here, the entry for 3 anomalistic months is 82d 15;56h, i.e., 3 · (27d 13;18,34h) = 82d 15;55,42h.

Note in MSS: “The cycle of the Sun is 365[d] 5;49,26[h]; two cycles are 730[d] 11;38[h].”

Table 22. Time from Mean to True Syzygy

Heading: “Table for finding the distance (*merḥaq*) of true conjunction or opposition from the mean”[1]

		[1]	[2]	[3]	...	[12]	[13]
Days of the Sun		0	16	32	...	171	182
Mean Sun		3s 0; 0°	3s15;47°	4s1;32°	...	8s18;36°	9s 0; 0°
Solar corr.		0; 0°	–0;30°	–0;58°	...	–0;18°*c*	0; 0°
[		0; 0°	–0;30°	–0;58°	...	–0;23°	0; 0°][2]
Corr. of the days		0; 0	–7	–5	...	0	0
Days of Anomaly	[Corr. of Anom.][3]						
0	0; 0[°]	0; 0h	–1; 6h	–2; 8h	...	–0; 40	0; 0h
[	0; 0	0; 0	–1; 6	–2; 8h	...	–0; 40 *d*	0; 0][4]
1	–1; 2	2;16	1; 10	0; 8 *b*	...	1; 36	2;16
[			1; 10	0; 8	...	1; 36	][5]
2	–2; 3	4:26	3; 21	2;20	...	3; 46	4;28
[			3; 20	2;18	...	3; 46	][5]
...							
27	0;34	1;22	–2; 28	–3;29	...	–2; 2 *e*	–1;23
[			–2; 28	–3;30	...	–2; 2	][5]
27[d 13;18h]*a*	0; 0	0; 0	–1; 6	–2; 8	...	–0; 40	0; 0
Solar corr.		0; 0°	0; 30°	0;58°	...	0; 18°	0; 0°
Corr. of the days		0	3	5	...	6	0
Mean Sun	3s	0; 0°	2s 14;13°	1s 28;28°	...	9s 11; 26°	9s 0; 0°
Days of the Sun	365d	5;49h	349d	333d	...	194d	180d *f*
Solar corr. acc. to Ptolemy		0; 0°	0;37°	1;13°	...	0;24°	0; 0°
[		0; 0	0;37°	1;13°	...	0;31°	0; 0°][6]

1. The heading for the table is missing in P; the headings for the columns in Ox are shifted one place to the left (where "left" refers to this transcription). Note that Ben Verga takes the solar apogee to be 90°.
2. These are the entries in Table 11, the equation of the Sun, where the maximum is 1:53°.
3. This column has no heading, but the entries in it agree with those in Table 13, the equation of the Moon.
4. Under the assumption, as described in the commentary, that: $\Delta t \quad c_s(\kappa)/[\min(v_m) - v_s(\kappa)]$.
5. Recomputed by adding the corresponding entries in the first row and the first column.
6. Computed from Ptolemy's solar equation table in *Almagest* iii.6 (maximum 2;23°) for the values of the mean Sun counted from the apogee, 3s 0;0°.

a. Read: 27d 13;18h. Note that 27d 13;18h is the length of an anomalistic month.
b. 8;0 Ox.
c. The entry below 171 days of the Sun, –0;18°, corresponds to 171° in Table 11; it seems that in this instance Ben Verga incorrectly interpreted the days of the Sun as degrees from apogee.
d. Computing with the solar correction of 0;18°, as in the heading.
e. 2;40 Ox.
f. 215 P mg. and Ox mg.; read: 183d ?.

Table 23: Parallax

Heading: [missing]

Cnc		Leo		...	Sgr	Cap
	Hours of half-daylight 7;20 b		Hours of half-daylight 7;13 f			
	(1)/(2)		(1)/(2)			
[7;27h]a		7;13h				
[7]	1;18h / 6°	7				
[6]	1;23 / 6	6	1;33h / 5; 6°h			
[5]	1;20 / 6	5	1;34 / 4;38			
[4]	1;18c / 5	4	1;32 / 3;55			
[3]	1;12 / 4	3	1;27 / 3;27			
[2]	0;46 / 3	2	1; 5 / 2;40			
[1]	0;32 / 4	1	0;48g / 2;30			
[noon]	0; 0 / 2;52	noon	0;12 / 3; 4			
		midheaven				
[1]	0;32 / 3;10 d	0;25	0; 0 / 3;31 i			
[2]	0;46 / 3;28	1	0;18 / 4; 2			
[3]	1;12 / 4;36	2	0;35 / 5;10			
[4]	1;18 / 5;30	3	0;56 / 6; 8			
[5]	1;20 / 6; 8	4	1; 5 / 7; 8			
[6]	1;23 / 6;31	5	1; 5 / 6;40 j			
[7]	1;18 / 6;32 e	6	1; 5 / 7;50 k			
[7;27]		7	1; 5 / 7;50 l			
		7;13				
Cnc		Gem		...	Aqu	Cap

(1) Correction of [longitude in] time
(2) Correction of latitude

Note: TC 8A (parallax tables, in the "Tables in Castilian") = Madrid, Biblioteca National, MS 3385, ff. 149r-151v.

a. The column for hours is missing in both manuscripts, but in Ox it may be concealed in the gutter due to tight binding.
b. 7;20 P; 720 Ox.
c. 1;11 MSS. (In Hebrew script '8' and '1' often look alike.)
d. 13;10 MSS; 3;10 TC 8A.
e. No entry in TC 8A.
f. 7;13 P; 703 Ox.
g. 10;41 Ox.
h. 5;10 TC 8A. (In Hebrew script '6' and '10' often look alike.)
i. 3;19 TC 8A.
j. 7:40 TC 8A.
k. 7;3 TC 8A. (In Hebrew script '3' and '50' often look alike.)
l. No entry in TC 8A.

Table 24. Eclipses

Heading. P: “Table for solar eclipses when the Moon is at mean distance *(orekh)*; Ta[ble] for establishing the durations of eclipses in latitude [...]”[1]

Ox: No heading.

	[Solar Eclipse]			[Lunar Eclipse]		
(1) App. dist. of the eclipse	(2) Dig.	(3) Half-duration	(4) lunar dist. from the node	(5) Dig.	(6) Half-duration	(7) Half-duration of totality
0:12°	12d	1; 3h *a*	11; 30° *f*	0d	0; 0h	0; 0h
0:42	11	1; 3*b*	10; 58 *g*	1	0; 36	0; 0
1:12	10	1; 2 *c*	10; 26	2	0; 58	0; 0
1:42	9	1; 1 *d*	9; 54	3	1; 1	0; 0
2:12	8	0; 59 *e*	9; 24	4	1; 8	0; 0
[2:42]	7	0; 57	8; 50	5	1; 16	0; 0
[3:12]	6	0; 54	8; 18	6	1; 21	0; 0
[3:42]	5	0; 51	7; 46	7	1; 28	0; 0
4:12	4	0; 46	7; 14	8	1; 32	0; 0
4:42	3	0; 41	6; 42	9	1; 37	0; 0
5:12	2	0; 35	6; 10	10	1; 40	0; 0
5:42	1	0; 25				
6:12	0	0; 0	5; 38	11	1; 43	0; 0
			5; 6	12	1; 45	0; 0
			4; 30	13	1; 48	0; 13
			4; 2	14	1; 50	0; 33
			3; 30	15	1; 52	0; 40
			2; 58	16	1; 53	0; 43
			2; 26	17	1; 53	0; 45
			1; 58	18	1; 54	0; 47
			1; 22	19	1; 56	0; 50
			0; 30	20	1; 57	0; 52
			0; 18	21	1; 58	0; 54
			0; 8	22	1; 57(!)	0; 57

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[1] There may be another word, hidden by a stain, after "latitude". The second part of this heading may mean that the durations of the eclipses were computed from the lunar latitude at mid-eclipse.

Headings for cols. 3 and 6: "Half-duration" P; "Duration" Ox (but the "half" may be hidden in the gutter).

Heading for col. 7: "totality" Ox (but the "half" may be hidden in the gutter); missing in P.

col. 1. [...] blank in both MSS.
a. 1;3 P; 13 Ox.
b. 1;3 P; 13 Ox.
c. 1;2 P; 12 Ox.
d. 1;1 P; 11 Ox.
e. 9;59 Ox.
f. 5;30 Ox.
g. 10;18 P.

Table 25: Digits of Eclipse

Heading: "Table for finding the area of the eclipsed luminary"

Digits of the diameter	Sun	Moon
1	0;20	0;30
2	1; 0	1;10 *b*
3	1;50 *a**	2; 5
4	2;50*	3;10
5	3;20*	4;20
6	4;40	5;50*
7	5;50	6;42*
8	7; 0	8; 0
9	8;20	9;10
10	9;40	10;20
11	10;50	11;20
12	12; 0	12; 0

a. 1;3 Ox.
b. 1;7 Ox.

*This entry differs from the corresponding entry in al-Battānī's zij (Nallino 1903-1907, 2:89).

Table 26: Length of Daylight

Heading: [illegible, and partly cut off at the top of the page]

Degrees of the Sun	Ari	Tau	Gem	...	Psc
0	12; 0h	13;30h	14;40h	...	10;33h
1	12; 2	13;32	14;41	...	10;36
2	12; 6	13;34	14;43	...	10;39
...					
28	13;22	14;35	15;12	...	11;54
29	13;28	14;38	15;12	...	11;57

P mg. adds: "Enter with the degree of the Sun and its zodiacal sign, and the place where they meet yields the number of hours and minutes, and it is the length of daylight when the Sun is located at that degree in that zodiacal sign."

Table 27: Declination

Heading: "The solar declinations (*merḥavei ha-shemesh*) according to al-Zarqāl and according to Ptolemy"

Mg. adds: "We see that the solar corrections according to al-Zarqāl and according to Ptolemy are in degrees of 30 minutes."

Argument	Declination	Declination
5	2; 0[°]	2; 1[°]
10	3;59	4; 2
15	5;58	6; 1
20	7;51	7;56
25	9;43	9;52
30	11;32	11;39
...		
80	23;10	23;28
85	23;27	23;44
90	23;38 *a*	23;55 *b*

a. Azarquiel's value for the obliquity is 23;33°, and the entries in his table are given at intervals of 3° (Millás 1943-1950, p. 174); the entries in this table are given at intervals of 5°, and seem to be based on an obliquity of 23;33° rather than of 23;38°.

b. Ptolemy's value for the obliquity is 23;51,20° (*Almagest*, i.15); the entries in this table are given at intervals of 5°, and seem to be based on an obliquity of 23;51° rather than of 23;55°.

Table 28. Normed Right Ascension

Heading: "Table for the ascensions of the zodiacal signs at mid-heaven, and they are the same for all horizons (i.e., geographical latitudes)"

Degrees of the Sun	Cap	Aqu	Psc	...	Sgr
0	0; 0°	32;12°	60;27°*a*	...	327;48°
1	1; 5	33;14	60; 9 *b*	...	328;51
2	2;10	34;16	64; 0	...	329;54
...					
28	30; 7	60;11	88;10	...	357;49
29	31; 9	61; 9	89; 4	...	358;57

a. Read: 62;7, with Levi ben Gerson (Goldstein 1974, Table 4), and Immanuel Bonfils (Munich, MS Heb. 386, 36b-37a).

b. Read: 63;4, with Levi and Bonfils.

Cap	2:	2;11	Levi and Bonfils.
Cap	29:	31;10	Levi and Bonfils.
Aqu	1:	33;15	Levi and Bonfils.
Aqu	2:	34;17	Levi and Bonfils.
Aqu	28:	60;14	Levi and Bonfils.
Psc	2:	64; 1	Levi and Bonfils.
Psc	29:	80; 5	Levi and Bonfils.
Sgr	1:	328;50	Levi and Bonfils.
Sgr	2:	329;53	Levi and Bonfils.
Sgr	29:	358;55	Levi and Bonfils.

Ox mg. adds: "The dog-days begin on July 14 and continue until Sept. 5."

Table 29: Geographical Coordinates (P 96a)

Names of the Places	Lat.	Long.	
Toledo	39;54°	28;16°	
Cordoba	38;30	27;14	
Sevilla	38; 8	55;40	(Read: 25;40)
Jaen	38;14	28; 4	
Granada	37;30	27;30	
Malaga	56;55	27;23	(Read 36;55)
Almeria	36;30	28; 5	
Sherez	36; 5	23;43	(Jerez, Spain)
Lisbon	39;38	22;54	
Santarin	40;50	23;42	(Santarem, Portugal)
Mu[r]cia	38;15	29;30 [a]	
Valencia	39;36	30;20	
Calat.w (?)	41; 8	58;58	(Read: 28;58; Calatayud, Spain) [b]
Zaragoza	41;30	29;45	
Barcelona	42;19	31;33	
Gerona	41; 6	28;32	
Valladolid	41;41	26;44	
Burgos	42;11	27;31	
Bitoria	42;46	28;14	(Vitoria, Spain)
Vayona	42;36	23;37	(Bayona, Spain) [c]
Salamanca	41;19	25;46	
Leon	42;46	26;19	

a. Murcia: long. 29;30°, lat. 37;30° Ox 235a (= Millás 1962, p. 238);
long. 29;35°, lat. 38;38° Ox 235b.
b. Calatayud: long. 28;51°, lat. 41; 0° Ox 235b.
c. Bayona: long. 23;33°, lat. 42;36° Ox 235b.

Table 1. Commentary:

The mean motion of the Sun, derived from the entry for 28y (0;14°), is 0;59,8,20,12°/d. With Levi ben Gerson's parameter for the mean motion of the Sun (0;59,8,20,8,44,6,3,14°/d: Goldstein 1974, p. 106), the motion in 28 Julian years is 0;13,50°, or about 0;14°, as in the text. Other well known values for this parameter do not yield as good agreement, e.g., with the Alfonsine parameter (0;59,8,19,37,19,13,56°/d), the motion in 28 Julian years is 0;12,21° or about 0;12°. In a note to Table 21 (see below), the length of the year is given as 365[d] 5;49,26[h], from which it follows that the daily mean motion of the Sun is 0;59,8,19,33°/d.

Table 2. Commentary:

The mean motion of the Moon, derived from the entry for 28y (114;59°), is 13;10,35,1,9°/d. The motion in 28 Julian years with the Alfonsine parameter (13;10,35,1,15,11,4,35°/d) is 114;59,19° or about 114;59°, as in the text.

The parameter added in the margin of P was obtained by dividing the rounded value for the daily motion of the Moon, 13;11°, by 24h, for 0;32,57,30 · 24 = 13;11° exactly. This value for the hourly motion of the Moon has no astronomical significance.

Table 3. Commentary:

The motion in lunar anomaly, derived from the entry for 28y (55;37°), is 13;3,53,57,5°/d. This parameter is close to, but not identical with, Levi ben Gerson's value for the daily motion in lunar anomaly (13;3,53,55,55,33,30°/d). With Levi ben Gerson's parameter, the motion in 28 Julian years is 55;33,44°, or about 55;34°.

Table 4. Commentary:

The motion of the lunar node, derived from the entry for 28y (–181;18°), is –0;3,10,32,34°/d. This parameter is confirmed by Table 5 for the motion of the Sun from the node. But it seems that there is a mistake in the sexagesimal thirds: instead of 32, one expects 37 or 38, as in al-Battānī, Levi ben Gerson, and the Alfonsine Tables. For example, the value in the Alfonsine Tables (ed. 1483) is –0;3,10,38,7,14,49,10°/d.

As in many other medieval tables, the result derived from this mean motion table has to be subtracted from 360° in order to obtain the longitude of the lunar ascending node.

Table 5. Commentary:

In Table 1, the mean solar motion is 0;59,8,20,12°/d, and in Table 4 the mean motion of the lunar node is –0;3,10,32,34°/d; hence the difference is 1;2,18,52,46°/d. Therefore, the motion in 28y is: 28 · 365;15 · 1;2,18,52,46°/d = 181;32,0°, or 181;32°, as in the text. This confirms that Ben Verga used an inaccurate parameter for the motion of the lunar node, as noted in the commentary to Table 4.

It is surprising that the dates for the radices here are the same as those in Table 21 for mean conjunctions (see below), but differ from those in the other planetary mean motion tables. Moreover, there are similarities between this table and one of Zacut's tables (Table AP 12, described in Chabás and Goldstein 2000, p. 118) as well as a table in the *Tabule verificate* (Madrid, Biblioteca Nacional, MS 3385, ff. 108r-109r; Table TV 10, described in Chabás and Goldstein 2000, pp. 29-30). In both cases there is a table for the solar elongation from the lunar node for each year in a period of 56 years. The entry in the Madrid manuscript for year 1 corresponds to March 1, 1461; and the entry for year 1 in Zacut's table corresponds to March 1, 1473. The underlying parameters are slightly different for, according to Zacut and the Madrid manuscript, in 28 years the motion in elongation is 6s 1;46°; whereas it is 6s 1;32° according to Ben Verga's table.

The purpose of this table is to help in deciding when one should compute the circumstances of an eclipse, for an eclipse is only possible when the Sun lies in the nodal zone, i.e., when the elongation of the Sun from the lunar node is less than the eclipse limit (see Table 24). I am aware of no table for this purpose other than the three discussed here.

Table 6. Commentary:

The mean motion of Saturn, derived from the entry for 28y (342;29°), is 0;2,0,33,26°/d. With Ptolemy's parameter (0;2,0,33,31,28,51°/d), the motion in 28 Julian years is 342;29,14°, or about 342;29°, as in the text.

The canons (R, f. 58b) give a worked example for finding the mean position of Saturn for Lisbon at noon on Feb. 15, 1474, presenting the following data (canons and table agree):

1468:	1s	4;11°
5y:	2s	1; 9
Jan.	0	1; 2
14d	0	0;28
Sum	3s	6;50°

Note that the date, noon, Feb. 15, 1474, is here interpreted to mean that 1473 complete years, 1 complete month, and 14 complete days, have gone by since the epoch of Incarnation.

Table 7. Commentary:

The mean motion of Jupiter, derived from the entry for 28y (130;6°), is 0;4,59,14,35°/d. With Ptolemy's parameter (0;4,59,14,26,46,31°/d), the motion in 28 Julian years is 130;5,35°, or about 130;6°, as in the text.

Table 8. Commentary:

The mean motion of Mars, derived from the entry for 28y (319;34°), is 0;31,26,37,4°/d. With Ptolemy's parameter (0;31,26,36,53,51,33°/d), the motion in 28 Julian years is 319;33,31°, or about 319;34°, as in the text.

The difference between the radices at intervals of 28y is 319;34° except for the interval from 1384 to 1412 where it is 319;26°. Emending the entry for 1384 to read 0s 0;58° would eliminate the discrepancy.

Table 9. Commentary:

The mean motion in anomaly for Venus, derived from the entry for 28y (6s 5;13°), is 0;36,59,29,44°/d. It follows that in a year of 365d the motion in anomaly is 225;1,56° (rounded in the text to 225;2°), and in 4 years 180;44,43° (rounded in the text to 180;45°). The variant for 28 years of 6s 5;3° seems to be a copyist's error, for the differences in the first subtable for radices at 28-year intervals are all 6s 5;13°. With the parameter of the Toledan Tables (0;36,59,29,27,29°/d: Toomer 1968, p. 44), the motion in 28 Julian years is 185;12,14°, or about 185;12°, which differs by only 0;1° from the value in the text. But with Ptolemy's parameter (0;36,59,25,53,11,28°/d), the motion in 28 Julian years is 185;2,5°, or about 185;2°, and this is farther from the value in the text. By my calculation, the parameter in the Toledan Tables is the same as that in al-Battānī's zij, although Kennedy (1956, p. 156) reports a value of 0;36,59,29,28,42,45°/d for Venus's motion in anomaly there.

Table 10. Commentary:

The mean motion in anomaly for Mercury, derived from the entry for 28y (92;13°), is 3;6,24,7,7°/d; it follows that in a year of 365d the motion in anomaly is 53;56,43° (rounded in the text to 53;57°), and in 4 years 218;53,17° (rounded in the text to 218;53°). With Ptolemy's parameter (3;6,24,6,59,35,50°/d), the motion in 28 Julian years is 92;12,40° or about 92;13°, as in the text.

Table 11. Commentary:

Although Ben Verga's entries for the solar equation are given to minutes and those in the preserved version of Ibn al-Kammād's table are given to seconds, Ben Verga has not rounded the entries of Ibn al-Kammād's table; rather, he has either recomputed the entries or, more likely, has used a copy that was better in some respects. The maximum equation here is 1;53° (for arguments 89° to 96°), rounded from Ibn al-Kammād's 1;52,44°. The apogee here is taken to be 90°, i.e., the argument of center is counted from Cancer 0° = 3s 0°. The rows are labeled "days", and to get the mean motion next to them, they are to be multiplied by the daily mean motion of the Sun, 0;59,8°/d. But for the other columns the "days" should be understood as "degrees".

The values in the heading labeled "days, hours, and parts of 1080" were obtained by dividing the argument of center (in multiples of 30°) by the daily mean motion of the Sun to yield the time since the Sun was at its apogee. But the results of dividing the argument of center by the entries in the table do not yield exactly the same daily mean motion of the Sun, although they are all very nearly equal to it:

30° / (30d 10h 505H) = 0;59,8,24°/d (reading 10h instead of 13h)
60° / (60d 20h 950H) = 0;59,8,33°/d
90° / (91d 7h 491H) = 0;59,8,20°/d
120°/ (121d 17h 920H) = 0;59,8,26°/d
150°/ (152d 4h 490H) = 0;59,8,17°/d
180°/ (182d 14h 990H) = 0;59,8,19,19,30°/d
210°/ (213d 1h 435H) = 0;59,8,19,19,30°/d
240°/ (243d 11h 960H) = 0;59,8,19,19,30°/d
270°/ (273d 22h 405H) = 0;59,8,19,19,30°/d
300°/ (304d 8h 930H) = 0;59,8,19,19,30°/d
330°/ (334d 19h 373H) = 0;59,8,21, 9,54°/d (reading 373H)

This set of numbers becomes coherent if one allows various 'minor' emendations, but some of them are not easy to assign to copyist errors. The difference between successive entries for zodiacal signs at the bottom of the columns, preserved in P, is 30d 10h 525H (except in the last case, unless the 373H is emended to 375H), and 12 · (30d 10h 525H) = 365d 5;50h = 365;14,35d, a reasonable value for the tropical year. Hence, one expects the entries at the top of the columns, beginning with Leo, to be: 30d 10h 525H (instead of 13h 505H); 60d 20h 1050H (instead of 950H); 91d 7h 495H (instead of 491H); 121d 17h 1020H (instead of 920H), and 152d 4h 465H (instead of 490H).

l ⅄ Note that in P (at the bottom of the page) 338d is written in aphabetic numerals as /3/38/; 304d as /30/4/; 273d as /27/3/; 243d as /2/43/; 213d as /2/13/; and 182d as /18/2/ (where each number between slashes is treated as a separate alphabetic numeral, and no alphabetic numeral is used for 'hundreds'). This suggests that the archetype for P used decimal place-value notation and this notation was misunderstood by the copyist. In contrast to P, Ox represents these numbers with the usual Hebrew alphabetic numerals. See also Table 21.

Table 12. Commentary:

This is Ptolemy's solar equation table (*Almagest*, iii.6), although the column for the correction is headed 'latitude' (or 'declination': *merḥav*).

Table 13. Commentary:

In the lunar equation table, there are several headings for the columns. For the row, "Mean", the entry is the mean motion in longitude for the number of days in the row above it; for the row, "Elong.", the entry is the mean elongation between the Moon and the Sun for the number of days above it; for the row, "Corr.", see al-Battānī's table for the lunar correction (column labeled "Aequatio anomaliae") where the argument is the double elongation; for the row, "Minutes of Proportion", again see al-Battānī's table for the lunar correction, where the argument is the double elongation (Nallino 1903-1907, 2:78-83). These values were presumably used by Ben Verga in computing the entries in the table proper. The columns are at 1-day intervals from 0d to 14d, and the rows are at 1-day intervals from 0d to 27d. The minimum lunar equation at syzygy is –5;1° for 0d of elongation and 7d of anomaly; recomputation yields –5;0,36°. The minimum in the table is –7;49° for 6d of anomaly and 7d of elongation; recomputation yields –7;22,44°. But the entry for 7d of anomaly and 7d of elongation is –7;37°, and recomputation yields –7;37,58°; hence, the entry –7;49° is an isolated error. Note that for al-Battānī the maximum lunar equation at syzygy is 5;1° and at quadrature 7;41° (for Ptolemy 5;1° and 7;40°, respectively).

The recomputations are all based on Ptolemy's second lunar model (with Ptolemy's parameters) and Judah ben Verga's mean motions: 13;10,35,1,9°/d for longitude; 12;11,26,40,57°/d for elongation; and 13;3,53,57,5°/d for anomaly. Slight changes in the mean motions will have little effect here.

The form of this double argument table is unusual, but Ben Verga also uses it in the tables for the planetary equations as well as in the table for the time from mean to true syzygy. Moreover, the table for the solar equation is presented in a similar fashion, even though there is only one argument.

Table 14. Commentary:

In the equation table for Saturn, there are several headings for the columns. The entries in the row, "days", are the quotients of multiples of 30° divided by the daily motion of center, for 180°/5375;1d = 0;2,0,33,28°/d, which is very nearly the mean motion of Saturn in Table 6 (0;2,0,33,26°/d). The center of Saturn is counted from 252°, Saturn's apogee according to Ben Verga. The entries in the row, "center", are arguments of center, counted from apogee. For the "correction of center" see al-Battānī's table for the correction of Saturn (column labeled "Aequatio centri"); and for "minutes of proportion" again see al-Battānī's table for the correction of Saturn, where the argument is the center, but the values here differ from those of al-Battānī (Nallino 1903-07, 2:108-113). I cannot identify the entries in the row labeled, "minutes of latitude". Many of these values were presumably used by Ben Verga in computing the entries in the table proper. The columns are at 30° intervals of the argument of center from 0° to 180°. The rows are at 14-day intervals from 0d to 364d, with an additional row for 365d.

The recomputations in the main table are all based on Ptolemy's model for Saturn with eccentricity 3;25, apogee 252°, and Judah ben Verga's parameters for the mean motion of Saturn (0;2,0,33,26°/d) and for the mean motion of the Sun (0;59,8,20,12°/d). The minimum entry in the table is −12;42° for 350 days and 90° of center; recomputation yields −12;41,30°. Slight changes in the mean motions will have little effect here.

The retrograde boundaries are the stationary points, counted from perigee. The entries in the latitude table were derived from the extremal values in Ptolemy's table for Saturn's latitude (*Almagest*, xiii.5).

In the canons (R, f. 58b) an undated example is given for finding the true position of Saturn: it is assumed that the mean position of Saturn on some day is 9s 12°, and that the mean Sun is 11s 4;48° (corresponding to

84d since the Sun was at Saturn's apogee in the heading for the rows). Then, according to the canons, the equation for Saturn is 1;30°; and this is indeed what one finds in the table. Hence the true longitude of Saturn would be 9s 13;30°.

Table 17. Commentary:

In the equation table for Venus, the headings are arranged in a similar pattern to that used for Saturn. The arguments of center in the headings are given at 30° intervals from 0° to 180°. The corrections of center in the headings seem to depend on a solar equation table with a maximum that is smaller than 1;53° (as in Table 11): the equation corresponding to 30° here is 0;53°, whereas in that table it is 0;55°. Similarly, for 60° the heading here has 1;33° (0;33° P), whereas the entry for 60° in Table 11 for the solar equation is 1;36°. The minutes of proportion in the headings correspond to those in al-Battānī's table for the correction of Venus (Nallino 1903-1907, 2:126-131, col. IV).

The arguments of anomaly are given at irregular intervals: 0d, 60d, 100d, 130d, 150d, 160d, 170d, ..., 424d, 454d, 484d, 524d, 584d. The entries for argument 584d (on the left) have been adjusted to allow the table to be used with the arguments shown below the table and the days displayed on the right.

The recomputed entries are all based on Ptolemy's model for Venus with al-Battānī's value for the eccentricities: 1;2,22,30 for the equation of center (cf. Nallino 1903-1907, 2:126-131, col. II), and 1;15 for the equation of anomaly (*loc. cit.*, cols. V-VII), with apogee at 90°. The mean motion parameters used in the recomputations are those of Ben Verga: 0;36,59,29,44°/d for the mean motion in anomaly of Venus (see Table 9), and 0;59,8,20,12°/d for the mean motion of the Sun (see Table 1). The minimum entries in the table are –48;5° for 354d and 120° of center, and –48;8° (–48;5° Ox) for 364d and 120° of center; recomputation yields –48;14,58° and –48;15,23°, respectively. Slight changes in the parameters have little effect here.

The limits of the retrograde arc in Ptolemy's table for the stations of Venus (*Almagest* xii.8; trans. Toomer 1984, p. 588) for 0°, 30°, and 180°

are: 165;51° (= 180° – 14;9°), 166;0° (= 180° – 14;0°), and 168;21° (= 180° – 11;39°), respectively.

Table 19. Commentary:

This table for planetary latitude corresponds to *Almagest*, xiii.5, at 30° intervals.

Table 20. Commentary:

This table for lunar latitude, with Ptolemy's value for the maximum lunar latitude of 5°, agrees with the corresponding table in al-Battānī (Nallino 1903-1907, 2:78-80).

Table 21. Commentary:

This table is to be used for finding the date and time of mean conjunction, and for providing the arguments for the Sun and the Moon in Table 22: Time from mean to true syzygy.

Note that Lisbon is mentioned in the heading of this table, but not in the heading of any other table. The order of the columns in subtable 1 differs from that in subtables 2 and 3. Subtable 1 is arranged for completed years at 28-year intervals. The days of conjunction refer to the number of days from the last mean conjunction of that year to Jan. 1 of that number of completed years. The entries, for instance, for 1456 refer to noon, Jan. 1, 1457, as is clear from the worked example in the canons (see below). So, according to Ben Verga, the last mean conjunction of 1456 took place 5d 8;22h before noon of Jan. 1, 1457, or Dec. 26, 1456, at 15;38h after noon. According to Levi ben Gerson's tables, there was a mean conjunction at Orange on Dec. 26, 1456, at 15;58h after noon (0;20h later than Ben Verga's time for this conjunction at Lisbon).[1] Levi ben Gerson's tables yield similar results for 1400 and 1512: for 1400 with Levi ben

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[1] According to Levi ben Gerson's tables, circle 1, year 8, a conjunction takes places on Dec. 2, 1328 at 4;59h after noon; circle 2: for 128y, add 24d 10;59h; the sum is then Dec. 26, 1456, at 15;58h after noon (cf. Goldstein 1974, pp. 225f).

Gerson's tables I compute 16d 0;50h (instead of 16d 1;12h); and for 1512 I compute 24d 3;57h (instead of 24d 4;16h). In other words, the times of these mean conjunctions at 56 year intervals, beginning with 1400, were 0;22h, 0;20h, and 0;19h earlier in Lisbon (according to Ben Verga) than the times in Orange (according to Levi ben Gerson), respectively.

In all 3 subtables, the days of conjunction refer to the number of days since the most recent mean conjunction, i.e., the entries give the number of days after multiples of 29d 12;44h (the length of the mean synodic month) have been cast out. From the entries for the days of the Sun in subtable 1, we learn that after 1456 completed years, i.e., on Jan. 1, 1457, the mean Sun was 201d 14;48h beyond its apogee (= 90° of longitude, according to Ben Verga). Hence the Sun was at its apogee on day 164 of that year, or about June 12.

The entry for 1456 for the days of conjunction in subtable 1 is found from the previous entry as follows: the entry for 1428 was 25d 11; 9h, and after 28 years (see subtable 2), the increase is 9d 9;57h; hence, the sum is 34d 21;6h. But this sum exceeds the length of a mean synodic month, and so 29d 12;44h is to be subtracted from it, yielding 5d 8;22h, as in subtable 1 for year 1456.

In the canons (R, f. 62a) there is a worked example for finding the time of mean conjunction near noon, Feb. 15, 1474. Ben Verga first takes the entry for 1456 (5d 8;22h), and adds to it the entries for 17 years (7d 13;48h) and for January (1d 11;16h) plus 14 days (having elapsed of February), for a total of 28d 9;26h. This amount falls short of a mean synodic month of 29d 12;44h by 1d 3;18h. Hence, mean conjunction will take place 1d 3;18h after noon of Feb. 15, or Feb. 16, 1474, at 3;18h after noon. The next worked example is for the days of the Sun since the time when the Sun was at its apogee. To find the days of the Sun for this conjunction in 1474, add the entry for 1456 (201d 14;48h), the entry for 17 years (365d 2;51h correctly in Table 21; in the canons it was miscopied as 365d 20;55h although the subsequent computation depends on the value 365d 20;51h), the entry for January (31d), and the time that has elapsed of February until the conjunction (15d 9;26h).[2] The sum is given as "613d

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[2] The author of the canons has misread his own data, for mean conjunction was computed to take place on Feb. 16, 3;18h after noon; hence the value here should be 15d 3;18h. The "28d 9;26h",

21;5h = 201d 14;48h + 365d 20;55h [read: 20;51h] + 31d + 15d 9;26h". Then, subtracting 365d 5;49h (the length of a tropical year) from 613d 21;5h, the result is the days of the Sun: 248d 15;16h; and this is said to be the interval from the time when the Sun was at its apogee to the time of the mean conjunction on Feb. 16, 1474, 3;18h after noon.

There is also a corresponding worked example for the days of the Moon at the time of this conjunction: to find the days and hours from the time the Moon was at the apogee of its epicycle, one has to add the entry for 1456 (17d 3;24h), the entry for 17 years (9d 5;17h), the entry for January (3d 10;37h), and the time that has elapsed of February (15d 9;26h [sic]; read: 15d 3;18h [see note 2]); the sum is 45d 4;44h and, after subtracting 27d 13;18h (the length of the anomalistic month), the result is 17d 15;26h (R, f. 62a). Since this table for conjunctions is most unusual and the canons in the St. Petersburg manuscript clearly refer to it, one can be reasonably sure that these canons were intended to be used with these tables. Moreover, The city of Lisbon is frequently mentioned in the canons, and it is mentioned once in the Oxford copy of the tables (but not at all in the Paris copy).

Let us consider the first entry for the days of the Moon in subtable 2. At the end of year 1 the Moon has completed 13 periods of anomaly with a remainder of 6d 18;58h (accurately, 6d 18;58,38h), i.e., 365d = 13 · (27d 13;18,34h) + 6d 18;58h.

In subtable 3, the first column gives the number of days of the Sun that have accummulated at the end of each month; in no case is the entry greater than the length of the tropical year (the principle being that if an entry were to exceed a tropical year, only the excess would be put there). The second column is for the days of conjunction, and the entry is the excess of the accummulated days at the end of each month less multiples of a mean synodic month. Similarly, the third column is for days of the Moon, and the entry is the excess of the accummulated days at the end of each month less multiples of an anomalistic month. Hence, for January the excess of 31d over a mean synodic month is 1d 11;16h = 31d − (29d

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above, seems to have led to the confusion, but that time interval served a different purpose: it is the time from the conjunction in January 1474 to Feb. 15, 1474 (less than a mean synodic month), used to determine the time of the mean conjunction in February 1474. The date, Feb. 15, 1474, was merely a preliminary 'guess' for the date of a mean conjunction, and has no particular significance.

12;44h), and the excess of 31d over an anomalistic month is 3d 10;37h (accurately, 3d 10;41h = 31d – [27d 13;18,34h]). For February, the excess of 59d over 2 anomalistic months is 3d 21;23h = 59 – (55d 2;37h), as in the text. So the error in the third column for January is isolated.

In the *Tabule verificate* (Madrid, Biblioteca Nacional, MS 3385, f. 104r) there is a table that corresponds to subtable 3 (omitting the days of the Moon), where the entry for December is 10d 5;12h (sic). But 365 – 12 · (29d 12;44h) = 10d 15;12h, and this is the entry for 1 year in our subtable 2 in the column, "days of conjunction" (cf. Chabás and Goldstein 2000, p. 25: Table TV 2).

In the note, 365d is written in P in alphabetic numerals as /36/5/ and 730d as /73/0/ (where each number between slashes is treated as a separate alphabetic numeral, and no alphabetic numeral is used for 'hundreds'). This suggests that the archetype for P used decimal place-value notation and this notation was misunderstood by the copyist. In contrast to P, Ox represents these numbers with the usual Hebrew alphabetic numerals; cf. Table 11.

Although the length of the tropical year is given in the note as 365d 5;49,26h, Table 21 is based on a tropical year of 365d 5;49,17h. To verify this, note that the entry for the days of the Sun for 28 years in subtable 2 is 0d 5;0h. In 28 Julian years there are 10227d, whereas in 28 tropical years of 365d 5;49,17h there are 10226d 19h; hence the difference is 0d 5;0h, as in the text. With a tropical year of 365d 5;49,26h, the result is 0d 4;56h. A tropical year of 365d 5;49,17h corresponds to a daily mean solar motion of 0;59,8,19,37°/d in agreement with the corresponding parameter in the Alfonsine Tables (0;59,8,19,37,19,13,56°/d), and in contrast to the parameter derived from Table 1 (0;59,8,20,12°/d).

Table 22. Commentary:

In using this table for finding the time from mean to true syzygy, days of the Sun and days of the Moon derived in Table 21 for mean conjunctions are to serve as the arguments.

The arguments for days of anomaly (or days of the Moon) on the left are at intervals of 1d from 0d to 27d 13;18h, with an extra row at mid-month for 13d 18;39h (only the '39' is visible in Ox; P has entries in this row, but no heading for it). Similarly the arguments for days of anomaly on the right (not displayed) go up from 0d in the last row to 27d 13;18h in the first row, as follows: 0d (in the same row as 27d 13;18h on the left); 0d 13;18h; 1d 13;18h; 2d 13;18h, ..., 13d 13;18h, 13d 18;39h, 14d 13;18h, ..., 27d 13;18h (in the same row as 0d on the left). The arguments on the right are to be used with the arguments at the bottom of the columns. The arguments for days of the Sun at the head of the 13 columns are: 0d, 16d, 32d, 48d, 64d, 80d, 96d, 111d, 127d, 145d, 156d, 171d, 182d, and the arguments at the bottom of the columns are found, as a rule, by subtracting the value at the head of the column from 365d (except for the entry at the bottom of column 1, 365d 5;49h, the length of the tropical year; and the entry at the bottom of column 13, as noted). The entries for the mean Sun in the headings of the columns are the sum of 90° (for the solar apogee) and the product of the number of days of the Sun (above them) and the mean motion of the Sun, 0;59,8,20°/d. The results of this recomputation differ slightly from those in the headings: 3s 0;0°; 3s 15;46°; 4s 1;32°; ...; 8s 18;33°; 8s 19;23°. In general, the entries for the mean Sun in the upper and lower headings of the same column are symmetric about the solar apogee, 90°.

The heading, "correction of the days" (*tiqqun ha-yamim*) seems to refer to the equation of time, but the entries in this row are not consistent with that interpretation; e.g., the entry for 0 days of the Sun is 0;0h (when the Sun is at its apogee), but this is not the case for the equation of time. As far as I can tell, these entries were not used in computing the entries in the table.

One enters the table with days of lunar anomaly at the left when the Sun is between apogee and perigee (i.e., days of the Sun at the head of the columns), whereas one enters with the days of lunar anomaly at the right when the Sun is between perigee and apogee (i.e., days of the Sun at the bottom of the columns). A positive (negative) entry in this table means that true conjunction is later than (earlier than) mean conjunction. In the manuscripts positive entries are designated 'after' (*aḥar*) and negative entries 'before' (*qodem*). These algebraic signs are appropriate when entering the table with the upper headings of the columns (and the headings of the rows on the left), but they are reversed when entering the table with the headings below the columns (and those to the right of the rows). Note that when the true Sun at mean conjunction is greater in longitude than the true Moon at that time, true conjunction takes place after mean conjunction.

The time from mean to true syzygy, Δt, depends on the solar and lunar equations at the time of mean conjunction, and the solar and lunar velocities at that time. A variety of solutions to this problem were available in the Middle Ages, but Ben Verga does not seem to have appealed to any of those known to me. His procedure for computing the entries in this table has not been determined with certainty, but it seems that he computed the first row and first column, and then used those entries to get the other entries in the table (or at least some of them), i.e., for each entry one adds the value at the beginning of the column to the value at the beginning of the row (see the computed values in rows ending with a superscript 5 in the table, above). The following analysis may help in understanding how this might be justified.

The general formula for finding this time interval, Δt, is:

$$[1] \qquad \Delta t = [c_s(\bar{\kappa}) - c_m(\bar{\alpha})]/[v_m(t) - v_s(t)],$$

where c_s is the solar correction of $\bar{\kappa}$, the center of the Sun; c_m is the lunar correction of $\bar{\alpha}$, the mean lunar anomaly; v_m is the lunar velocity; and v_s is the solar velocity, both of which are time dependent. The difficulty is that both v_m and v_s vary in the time interval from mean to true syzygy. Ptolemy solved this problem by an iteration procedure, and John of Saxony described a different iteration procedure in his canons to the Parisian version of the Alfonsine Tables. The most successful, and user-friendly, solution has been attributed to Nicholaus de Heybech (Chabás and Goldstein 1992).

A simplication of equ. [1] that yields an approximate value for Δt is:

$$[2] \qquad \Delta t = c_s(\bar{\kappa})/[\min(v_m) - v_s(\bar{\kappa})] - c_m(\bar{\alpha})/[v_m(\bar{\alpha}) - \min(v_s)].$$

Equ. [2] may have been used to compute the entries in the first column and first row, respectively. Recomputation with this formula yields exact agreement with the entries in the first row of the table ($c_m = 0°$), where c_s is taken from the heading of the column, $\min(v_m)$ is taken to be either

0;29,35°/h (Levi ben Gerson) or 0;29,37°/h (John of Genoa: see Goldstein 1992), and $v_s(\bar{\kappa})$ is taken from al-Battānī's table for solar velocity, whose entries range from 0;2,23°/h to 0;2,33°/h (see the row ending with a superscript 4 in the table, above).

Table 22A. Time from mean to true syzygy (Ben Verga compared with computations based on John of Genoa's lunar velocity table)

	Ben Verga		Ben Verga / Comp.		T – C	John of Genoa
days	lunar anom.	lunar corr.	(Sun's center: 0°)		min.	$v_m(\bar{\alpha})$
0	0; 0°	0; 0°	0; 0h	0; 0, 0h	0	0;29,37°/h
1	13; 4	–1; 2	2;16	2;16, 6	–0	0;29,43
2	26; 8	–2; 3	4;26	4;28,12	–2	0;29,54
3	39;12	–2;58	6;20	6;23,15	–3	0;30,15
4	52;16	–3;45	7;51	7;56,45	–6	0;30,42
5	65;19	–4;23	9;16	9; 6,20	10	0;31,16
6	78;23	–4;49	9;38	9;45,49	–8	0;31,59
7	91;27	–5; 1	9;47	9;54,24	–7	0;32,46
8	104;31	–4;57	9;22	9;30,14	–8	0;33,38
9	117;35	–4;38	8;36	8;41,15	–6	0;34,23
10	130;39	–4;20	7;20 *a*	7;54;24	–34	0;35,16
11	143;42	–3;12	5;41	5;43, 2	–2	0;35,58
12	156;47	–2; 9	3;48	3;47, 5	1	0;36,28
13	169;51	–0;57	1;39	1;39,22	0	0;36,48
14	182;55	0;17	–0;30	–0;29,31	0	0;36,56

a. Perhaps a copyist's error.

To recompute the entries in the first column, we note that when the center of the Sun is 0°, its correction is 0° and its velocity is at its minimum, 0;2,23°/h (eliminating the effect of the solar correction and fixing the solar velocity). We then tried values for lunar velocity, derived from different tables of lunar velocity, but agreement was not exact with any of them, even with John of Genoa's table that yielded better results than the others. Table 22A displays the comparison of Ben Verga's entries with those computed with John of Genoa's lunar velocity table (see especially the column for "T – C", in minutes of time, where "T – C" means: text – computation). As is evident, the agreement is not good enough to claim that this table was used by Ben Verga, but I am not aware of a table that is satisfactory for this purpose. The recomputed entries were found using the following equation:

$$\Delta t = -c_m(\bar{\alpha})/[v_m(\bar{\alpha}) - \min(v_s)],$$

where $c_m(\bar{\alpha})$ is the value given in the heading on the left of each row in Table 22. Then, the values for v_m are those derived from John of Genoa's table for lunar velocity, and $\min(v_s)$ is taken as 0;2,23°/h.

In the canons (R, f. 62a-b) there is a worked example for finding the true conjunction that corresponds to the mean conjunction of Feb. 16, 1474, at 3;18h after noon. At that time, the days of the Sun were computed to be 248d 15;16h, and the days of the Moon to be 17d 15;26h (see commentary to Table 21). Using linear interpolation, Ben Verga claims that the time from mean to true conjunction is –4;24h, and hence true conjunction takes place on Feb. 15, 1474, 22;54h after noon. In Table 22 (using arguments at the right side of the rows, and at the bottom of the columns), the entry coresponding to 17d 13;18h of the Moon and 254d of the Sun is –4;4h; whereas for 17d 13;18h of the Moon and 239d of the Sun, the entry is –4;27h. Similarly, for 18d 13;18h of the Moon and 254d of the Sun the entry is –4;49h, whereas for 18d 13;18h of the Moon and 239d of the Sun it is –5;38h. Hence, Ben Verga should have found –4;17h (instead of –4;24h).

According to the tables of Abraham Zacut (1496, f. 161v), there was a true opposition at Salamanca on Feb. 17, 1504 (o.s.), or Feb. 17, 1505, at 23;7h (with a correction for each cycle of 31 years of 0;27h). Hence there was a true conjunction 31 years earlier, on Feb. 15, 1474, at 23;34h (Salamanca time). With modern coordinates, the difference in longitude between Salamanca (5;40°W) and Lisbon (9;8°W) is 3;28°, or 0;14h, but according to Zacut (f. 168r), the difference in longitude between them is 2;52° (= 25;46° – 22;54°), or 0;11h. Hence, according to Zacut, true conjunction on Feb. 15, 1474 for Lisbon took place at 23;23h after noon.

According to modern computation for Baghdad, true conjunction took place on Feb 16, 1474 at 14;57h after midnight, or 2;57h after noon (Goldstine 1973). The difference in longitude between Baghdad (44;26°E) and Lisbon (9;8°W) is 53;34° or 3;34h. Hence, true conjunction at Lisbon took place on Feb. 15, 1474 at 23;23h after noon. Thus, modern computation confirms the result based on Zacut's data, and not the result stated by Ben Verga that is 0;29h earlier.

Table 23. Commentary:

This table is presumably intended as a parallax table for the latitude of Lisbon. The shortest half-daylight here is 4;33h which implies that longest half-daylight should be 7;27h and, with Ptolemy's obliquity of 23;51°, this corresponds to a latitude of about 40° (probably the intended latitude for Lisbon). Latitude 40° is associated with longest daylight 14;54h on several astrolabes from Islamic Spain (al-Andalus): see King 1999, pp. 23ff. For an example of a geographical list where the latitude of Lisbon is 40°, see Madrid, Biblioteca Nacional, MS 3349, f. 11r, a fourteenth century manuscript that includes Portuguese material (cf. Chabás 1996a, p. 264). In Table 29 the latitude of Lisbon is 39;38°. However, in the Toledan Tables, there is a table for parallax with a heading that indicates it is for latitude 39;54° or longest daylight 14;51h (Toomer 1968, pp. 98ff). The values for half-daylight in it are 7;27h (Cnc), 7;13h (Leo), 6;40h (Vir), ..., 4;47h (Sgr), and 4;33h (Cap); whereas here the values are 7;20h (Cnc), 7;13h (Leo), 6;40h (Vir), ..., 4;46h (Sgr), and 4;33h (Cap). It would seem that the table here was 'borrowed' from a table intended for Toledo. On the other hand, the display of parallax in longitude in units of time (rather than in degrees of longitude) is unusual, but found in the tables of Jacob ben David Bonjorn, the *Tabule verificate*, the "Tables in Castilian", the tables of Abraham Zacut (Chabás 1991, p. 307; Chabás and Goldstein 2000, pp. 31f, 40-44, 62, 132), and the tables of Ibn Isḥāq (Mestres, 1996, p. 423).

The entries in this table are clearly corrupt. For the parallax in latitude for Cancer and Leo the entries are corrupt versions of the corresponding entries in the "Tables in Castilian", Madrid, Biblioteca Nacional, MS 3385,ff. 149r-151v: Table TC 8A (see Chabás and Goldstein 2000, p. 41).

For Cancer the minutes are omitted here for the first several entries in column (2), but they appear in Table TC 8A. I have no explanation for the entries in the column for longitude, but they are of the same order of magnitude as those in Table TC 8A.

Table 24. Commentary:

In this eclipse table, cols. 1 to 3 relate to solar eclipses, and cols. 4 to 7 relate to lunar eclipses. In both cases the table is arranged for increments in the digits of eclipse (on the diameter of the eclipsed body) in cols. 2 and 5. The adjusted argument of latitude counted from the lunar node, given in cols. 1 and 4, serves as argument for finding the durations in cols. 3, 6, and 7, respectively. For solar eclipses, the distance from the node increases uniformly by 0;30° from 0;12° to 6;12° for increments of 1 digit; cf. *Almagest* vi.8, where the argument of latitude also increases by 0;30° for increments of 1 digit.

The eclipse limit for a solar eclipse is 6;12° from the node, and for a lunar eclipse it is 11;30° from the node. In the *Almagest* vi.8, the eclipse limit for a solar eclipse is 6° on either side of each node when the Moon is at greatest distance, and 6;24° on either side of each node when the Moon is at least distance. The parameter here, 6;12°, then, is the mean value and is intended for the mean distance of the Moon, i.e., no allowance is made for the variation in lunar distance from the Earth. Similarly, for lunar eclipses, in the *Almagest* vi.8, the eclipse limit for a lunar eclipse is 10;48° on either side of each node when the Moon is at greatest distance, and 12;12° on either side of each node when the Moon is at least distance. Once again, the eclipse limit here for lunar eclipses, 11;30°, is the mean value and is intended for the mean distance of the Moon.

The durations in the table do not allow for variation in lunar (or solar) velocity, in contrast to the corresponding tables in the *Almagest* vi.8, al-Battānī's zij (Nallino 1903-1907, 2:90-91), the Toledan Tables (Toomer 1968, pp. 86ff), the Almanach of Azarquiel (Millás 1943-1950, pp. 231, 234), the Alfonsine Tables (ed. 1483, ff. m1v-m2v), etc. Moreover, instead of the half-durations here, in those tables one finds the arc from first contact to mid-eclipse, so that the duration is to be determined as the product of this arc times the appropriate velocity in elongation (i.e., the difference between the lunar and solar velocities).

The zij of Yaḥyā ibn Abī Manṣūr has a double argument table for solar eclipses where the entries in each column display the half-durations for velocities in elongation from 0;27,30°/h to 0;33,30°/h at intervals of 0;1°/h (Kennedy and Faris 1970, p. 191; Escorial MS Ar. 927, f. 13r). The entries in the column for 0;33,30°/h come closest to those in Ben Verga's table. The same table is found, with textual variants, in the zij of Ibn al-Kammād ([K] Chabás and Goldstein 1994, p. 23; Madrid, Biblioteca Nacional, MS 10023, f. 54r), and in the Tables of Barcelona ([B] Millás 1962, p. 237; cf. Chabás 1996b, pp. 511f). For purposes of comparison, it is best to use the zij of Ibn al-Kammād, because the column in Yaḥyā for 0;33,30°/h is corrupt. Table 24A displays a comparison of Ben Verga's entries with those in Ibn al-Kammād's zij, as well as the recomputed arcs from first contact to mid-eclipse derived from the entries in Ben Verga with a mean velocity in elongation of 0;30,28°/h (= 0;32,56°/h – 0;2,28°/h), and the recomputed arcs from the entries in Ibn al-Kammād with a velocity in elongation of 0;33,30°/h. The arcs derived in this way from Ben Verga's table lie between the minimum and maximum values in al-Battānī's table, whereas those derived from Ibn al-Kammād do not (with 1 exception: 2 digits).

Ben Verga's table for lunar eclipses is very similar to Table HG 21 in Zacut's *ha-Ḥibbur ha-Gadol* (Chabás and Goldstein 2000, pp. 63-64; Lyon, MS Heb. 14, f. 138r), ascribed by Zacut to Judah ben Asher: the column for the lunar distance from the node is the same, but for copyist's errors; and the durations are arranged in the same way, although the entries are systematically different. The entries in cols. 6 and 7 display the durations from first contact to mid-eclipse and from inner first contact to mid-eclipse, respectively.

In the *Almagest*, the entry for a central lunar eclipse for the arc from first contact to mid-eclipse (when the Moon is at its closest distance to the Earth) is 0;35,20° + 0;28,16° = 1;3,36°. If we divide this arc by the mean velocity in elongation, 0;30,28°/h, we find 2;5h, instead of the last entry in col. 6, 1;57h (probably a mistake for 1;59h). If we divide 0;28,16° (the arc from inner first contact to mid-eclipse) by the mean velocity in elongation, we find 0;56h (instead of the last entry in col. 7, 0;57h). Recomputation with the Toledan Tables yields slightly different results, but it does not seem that Ben Verga's used either the *Almagest* or the Toledan Tables here. I have not found a plausible way for getting closer to the entries in Ben Verga's table.

Table 24A: Solar Eclipse

Digits	Ben Verga Half-dur.	Recomp. Arc[1]	Ibn al-Kammād Half-duration	Recomp. Arc[2]
12	1; 3h	0;31,59°	1; 5h [a]	0;36,18°
11	1; 3	0;31,59	1; 4	0;35,44
10	1; 2	0;31,29	1; 3	0;35,11
9	1; 1	0;30,58	1; 1	0;34, 4
8	0;59	0;29,58	1; 0	0;33;30
7	0;57	0;28,57	0;57	0;31,50
6	0;54	0;27,25	0;53	0;29,36
5	0;51	0;25,54	0;49	0;27,22
4	0;46	0;23,21	0;46	0;25,41
3	0;41	0;20,49	0;40	0;22,20
2	0;35	0;17,46	0;32 [b]	0;17,52
1	0;25	0;12,42	0;24	0;13,24
0	0; 0	0; 0, 0	[0; 0][c]	[0; 0, 0]

1. Computed from Ben Verga's entries with a velocity in elongation of 0;30,28°/h.
2. Computed from Ibn al-Kammād's entries with a velocity in elongation of 0;33,30°/h.

a. In Yaḥyā's zij, the entry for 12 digits is 1;5; in K and B the maximum entries for 11;40 digits are 1;4 and 1;5, respectively.

b. 0;32 B; 0;30 K.

c. For argument 0;15 digits, the entry is 0;6h K; 0;5h B (0;22h in Yaḥyā's zij, but this is probably a copyist's error); there is no argument 0 digits in K or B.

Table 25. Commentary:

In this table for converting linear digits of eclipse to the area of the eclipsed body, the entry for 3 digits of the diameter in the column for the Sun is 1;50, as is the case in the Toledan Tables (Toomer 1968, p. 113) and in Zacut's table. On the other hand, Ptolemy's *Almagest* (vi.8), *Handy Tables* (Stahlman 1959, p. 258), al-Battānī (Nallino 1903-1907, 2:89), Juan Gil (London, Jews College, MS Heb. 135, f. 97a), and al-Khwārizmī (Suter 1914, p. 190, Table 76) all have 1;45. The entry for 5 digits in the column for the Sun is 3;20, as in the Toledan Tables. Moreover, the entries for 2, 6, and 7 digits in the column for the Moon agree with those in Zacut's table (Zacut 1496, f. 65r); the entry for 6 digits in the Toledan Tables and al-Battānī's zij is 5;30 (rather than 5;50); and the entry for 7 digits in the Toledan Tables is 6;42 (as it is here) but 6;45 in al-Battānī's zij. There are a few other cases of entries here that differ from those in the Toledan Tables, where the entry for 4 digits (Sun) is 2;40 (as in Zacut's table) and the entry for 11 digits (Moon) is 11;30.

Table 26. Commentary:

The table for the length of daylight is for an unstated geographical latitude. With an obliquity of 23;51°, longest daylight of 15;12h corresponds to a latitude of 42;37°; in Table 29 the latitude of Bayona (on the Atlantic coast of Spain just north of the Portuguese border) is 42;36°. With an obliquity of 23;33°, longest daylight of 15;12h corresponds to a latitude of about 43° (in some medieval sources this is the latitude of Valladolid, but in Table 29 the latitude of Valladolid is 41;41°). It is not clear that this table belongs to the set of tables by Ben Verga for Lisbon.

Table 27. Commentary:

This table for solar declination appears on the same page as the table for the mean motion of the Sun (Table 1), and the table for the solar equation according to Ptolemy (Table 12). The marginal note here might have been intended for one of the other tables but, in any case, it makes little sense. One might emend the text, changing the translation from "degrees of 30 minutes" to "signs of 30 degrees" (in contrast to signs of 60 degrees, as in the Alfonsine corpus), but there is little justification for assuming that the author or copyist was aware of this ambiguity in the term "sign".

The entry for 15° here for Azarquiel, 5;58°, agrees with the entry in Azarquiel's table of declination (Millás 1943-1950, p.174), but in the version of this table preserved in Ibn al-Kammād's zij (Madrid, Biblioteca Nacional, MS 10023, f. 35v) and in Zacut's tables (1496, f. 25r) the entry for 15° is 5;56°. Note that Ibn al-Kammād and Zacut display entries for each degree from 1° to 90°.

Table 28. Commentary:

Normed right ascension, α', is counted from Cap 0°, and it is defined as follows: $\alpha'(\lambda) = \alpha(\lambda) + 90°$, where $\alpha(\lambda)$ is the right ascension counted from Ari 0° (cf. Neugebauer 1962, p. 48). Most of the entries for normed right ascension agree with those in Levi ben Gerson's table (a copy of which is included in Immanuel Bonfils of Tarascon's version of al-Battānī's zij: Munich, MS Heb. 386, 36b-37a); but the frequent differences of 0;1 suggest that this table was computed independently with the same underlying parameter for the obliquity, 23;33°. The agreement with al-Battānī's table is also close (Nallino 1903-1907, 2:61-64).

The "dog-days" refer to the period of hot weather during the summer, associated in antiquity with the Etesian winds and the heliacal rising of the dog-star, Sirius. The duration was generally taken to be 40 days (as in Pliny), but varies in different sources. Here the duration is 53 days: July 14 to Sept. 5. See Pseudo-Bede, *De minutione sanguinis, sive de phlebotomia* (Migne 1862, col. 959c), where we are told that the days from the 15th Kalends of August to the Nones of September are called the dog-days (*caniculares dies*), i.e., from July 18 to Sept. 5 (49 days). A similar passage occurs in *The Customs of London* (Arnold 1502; 2nd ed. 1811, p. 172): "The Canycular daies begynne ye xv. kalendas of August and endure to the iiij. nonas of Septembre in which seson there is gret perill to take syknesse and it is perillus to take drinks or medecyns or too be lat blod but if it be for gret nede and that must be aftir the middis of the day", i.e., the dog-days are from July 18 to Sept. 2 (46 days). See also Aristotle, *Meteorology*, i.5 361b35; idem, *Metaphysics*, vi.2 1026b34;

Pliny, *Nat. Hist.* ii.123-124 (ed. Beaujeu 1950, pp. 55, 203). According to Pliny, the Etesian winds begin on July 20, 2 days after the heliacal rising of Sirius, and continue for 40 days. The date of Pseudo-Bede's treatise is uncertain, but it may have been composed as late as the end of the thirteenth century: see Jones 1939, pp. 86-89.

Table 29. Commentary:

All the cities in P's list are in Spain and Portugal. Ox has several geographical lists on ff. 235a-235b in a hand that differs from the previous tables. They include cities outside the Iberian peninsula and have not been reproduced here.

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