A Second Manuscript of the *Mumtaḥan Zīj*

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1 Introduction

Until now the *Mumtaḥan Zīj* by Yaḥyā ibn Abī Manṣūr, one of the earliest extant Islamic astronomical handbooks with tables,[1] has been known only from a single manuscript of a late recension. Yaḥyā's zīj was based on the results of the observational program carried out in Baghdad on the order of the Abbasid caliph al-Maʾmūn during the years AD 828–829. It consists of a mixture of materials of Indian and Iranian origin and the first systematic attempts to calculate Ptolemaic tables for planetary motions and spherical astronomical quantities on the basis of updated values for the underlying parameters. What has been thought to be the only surviving copy of the *Mumtaḥan Zīj* is contained in MS Escorial árabe 927. It is not complete, and is supplemented by texts and tables of a later date, for instance by Abu 'l-Wafāʾ (Baghdad, second half of the tenth century) and Kūshyār ibn Labbān (Iran, ca. 1000). One of the most important objectives of previous research on the Escorial manuscript, in particular by Vernet, Kennedy and Viladrich, has been to distinguish between the original material stemming from Yaḥyā and later additions.

In June 2004, during a visit to the Universitätsbibliothek in Leipzig, I had the chance to look at the manuscript Vollers 821 (formerly DC 120) in some detail. Since both the first and the last folios of this volume deal with calendar conversion, it was catalogued in section 41 ("Chronologie und Kalender") of Vollers 1906 as a purely chronological work. However, it

[1] Somewhat over one hundred Islamic zījes were briefly described in the standard work Kennedy 1956a. Meanwhile more than two hundred works in Arabic and Persian are known, of which more than one hundred are extant. In the second issue of this journal (2001), King and Samsó published a broad overview of Islamic zījes and the categories of tables they contain. An extensive new survey of Islamic astronomical handbooks with detailed information on all extant works is currently being prepared by the present author.

turned out that the manuscript is in complete disorder, and that in between the chronological sections there is a whole range of materials of the kind that is usually found in zījes. On first inspection, I noticed that the manuscript contains the same planetary mean motions and equations as found in the Escorial copy of the *Mumtaḥan Zīj*, and that various of its tables and chapters are attributed to Yaḥyā ibn Abī Manṣūr, al-Maʾmūn, and the important tenth-century astronomer Ibn al-Aʿlam, who was famous for the accuracy of his observations but whose zīj is lost.

Two months later, an extensive investigation of a microfilm of the Leipzig manuscript confirmed that it contains much of the material in the Escorial copy that has been recognized as belonging to the original *Mumtaḥan Zīj*. Besides the planetary mean motions and equations, it includes an elementary section on chronology, a long section on spherical astronomy with some tables, and the highly interesting material on solar and lunar eclipses that has been associated with Yaḥyā. Moreover, the Leipzig manuscript contains some chapters and tables attributed to al-Maʾmūn and Yaḥyā that are not present in the Escorial copy, such as tables for calculating lunar eclipses by *manzila*s and a table for year transfers. Although no title page, preface, and colophon are found anywhere in the Leipzig manuscript, a passage on fols. 47^{r}–47^{v} confirms that it constitutes a recension of the *Mumtaḥan Zīj*. This passage concludes a long introductory chapter on the planets and their spheres with the statement that Ibn al-Aʿlam's tables for Mars were included in "this modified Maʾmūnic zīj", because his observations were the most correct (see section 3L and Figures 3a and 3b below).

Besides the original Maʾmūnic material, the Leipzig manuscript turned out to contain chapters and extracts from other early Muslim astronomers, namely, Ḥabash al-Ḥāsib, who was present in Baghdad and Damascus at the time of the observations made for al-Maʾmūn but only finished his impressive zīj after AD 860 in Samarra, and the famous observer from Raqqa, al-Battānī, who wrote his *Ṣābiʾ Zīj* around the year 900. The inclusion of an oblique ascension table for Mayyāfāriqīn and some nearby localities suggests that the compiler of the particular recension extant in Leipzig lived in what is now southeastern Turkey. That the manuscript was at least to some extent used in this region is confirmed by one of the very few marginal notes in a different hand, which gives the latitude of Isʿird (or: Siʿird) as $37^{\circ}18'$ and its longitude as $76^{\circ}28'36''$ above a text on solar eclipses on fol. 40^{v}.

All in all, the Leipzig manuscript includes more materials from the early period of Islamic astronomy than the Escorial copy and none that are essentially later than Ibn al-Aʿlam. It thus constitutes a highly important source for our knowledge of Islamic astronomy in the ninth and tenth centuries and for the reconstruction of the original zījes of Yaḥyā ibn Abī Manṣūr and Ibn al-Aᶜlam. Since the Leipzig and Escorial manuscripts both replace Yaḥyā's mean motions and equations for Mars by those of Ibn al-Aᶜlam, they probably ultimately go back to the same recension of the *Mumtaḥan Zīj* (presumably compiled in the tenth century), but the Leipzig copy seems to have reached its present form at an earlier stage than the Escorial one.

The purpose of this article is to make the contents of the Leipzig manuscript known to the extent that any scholars of the history of Islamic astronomy can determine which parts of the work may be of interest to them. Since the manuscript is in great disorder, in Section 2 an attempt is made to reconstruct the order of the original manuscript. In Section 3, the complete contents of the manuscript, arranged by topic, is described in some detail. A summary at the end of this section gives an overview of the sources of the materials in the Leipzig manuscript and the most important differences from the Escorial manuscript. The Appendix provides a complete table of contents in the present order of the folios with indications of which folios originally belonged together and where interrupted texts and tables are continued.

Throughout the remainder of this article, I will use the siglum **L** for the Leipzig manuscript and **E** for the Escorial copy. Because of the confusing folio numbering in **E** (the numbers appear on the verso sides of the folios and number 30 has been left out), I refer for this manuscript to the page numbers in the facsimile edition Sezgin 1986. An overview of the contents of **E**, also indicating the folio numbers, can be found in Vernet 1956. Occasionally I will refer to the most original of the two manuscripts of the zīj of Ḥabash al-Ḥāsib, namely MS Istanbul Yeni Cami 784/2, fols. 69^v–229^r, by the siglum **H**. This manuscript is abstracted in Debarnot 1987, with a comparison with the later recension MS Berlin We. 90 (Ahlwardt #5750) in an Appendix. Although Ḥabash's zīj was to a large extent based on the observations made under al-Maʾmūn, it has only very little material in common with the *Mumtaḥan Zīj*. Finally, the *Ṣābiʾ Zīj* of al-Battānī, extant in the unique copy MS Escorial árabe 908, is edited and commented upon in Nallino 1899–1907.

Only scattered references are included in this article to treatments of topics discussed in zījes. A general overview of the subject matter of these works can be found in Kennedy 1956a, pp. 139–145, with some additions in King & Samsó 2001. Numerous studies on technical subjects from zījes are collected in Kennedy *et al.* 1983 and King 1986. For further information on the astronomers mentioned, the reader is referred to Rosenfeld & İhsanoğlu 2003, Sezgin 1978, the *Dictionary of Scientific Biography*, and the *Biographical Encyclopedia of Astronomers* (to appear with Kluwer in 2004 or 2005).

2 Rearranging the manuscript

The Leipzig manuscript is written on fragile paper, now partially damaged. The size of the pages is 17 × 25 cm, of which text and tables cover approximately 12 ×18,5 cm. The written part of the pages is surrounded by a double frame, but the lines of script (between 17 and 19 on a page) are often not straight. Except for the last two folios, the whole manuscript is written in a somewhat sloppy naskh, presumably of northern Iraqi provenance, which can be dated to roughly the year AD 1200. The text has relatively few diacritical dots, and especially *alif* and *wāw* are mostly connected to the following letters. Non-final *kāf*s frequently occur with a miniature *kāf* above the vertical stroke, and numbers are almost always written out in words (in **E**, the same numbers are mostly written in *abjad* or Hindu numerals). Another typical feature of the manuscript is that the punctuation marks used at the end of chapters or "paragraphs", large Arabic letters *hāʾ* with a dot in the middle, are filled with red ink. Red is further used for nearly every chapter title and for certain columns in the tables; the red is very clear in the manuscript and can be read reasonably well from the microfilm that I have used.

As has been mentioned in the introduction, **L** is bound in complete disorder. For instance, the chronological chapters and tables at the beginning and end of the work, which led Vollers to believe that the whole contents was chronological, are in fact part of one larger section on date conversion. Below an attempt is made to reconstruct the original order of the manuscript, which is made particularly difficult since the chapters (and tables) are not numbered and no catchwords are provided on the verso pages. In many cases, texts and tables can be seen to continue in very different parts of the manuscript. In some cases, the beginning or end of a chapter (and in only one case of a table) appears to be missing completely.

In the suggested original order of the folios presented below, a somewhat thicker and longer line between ranges of folios indicates a *definite* break in the manuscript: the text or table preceding such a break does not end at the end of the last folio of the range but has no continuation anywhere in the manuscript, and similarly the beginning of the text or table on the first folio after such a break is not contained in the manuscript. A thinner and shorter line preceded by a question mark indicates a *possible* break in the manuscript: a text or table ends at the end of the last folio before such a break and a new text or table starts at the beginning of the first folio after it. I have used two criteria for combining ranges of folios starting or ending with possible breaks: consecutiveness of folio numbers and consistency of topics. However, since also originally **L** appears to have been a hodgepodge of different materials from different sources thrown together in a more or less random order, in particular the second criterion is a rather arbitrary one. Asterisks before or after the brief descriptions of the topics in the list below indicate that the section concerned is continued from, or continues on, a folio at a different place in the manuscript.

missing:	• title page, preface, first part of section on chronology
113–129	• *chronology (with extract from al-Battānī)
	• general introduction on the heavenly sphere, divisions of the ecliptic, multiplication and division of parts of degrees (associated with al-Battānī)
	• on the setup of an almanac (*taqwīm*)
	• lunar latitude*
131–151	• *lunar latitude
	• planetary visibility
	• spherical astronomy
	• "applications" (*ittiṣālāt*)
	• treatise on a sundial for seasonal hours
	• chronology, with table for date conversions*
1–2	• *chronology: tables for date conversions*
34	• *chronology: table for date conversion
	• introduction to planetary motions*
45–50	• *introduction to planetary motions
	• mean motions, true longitudes, planetary stations*
35	• *planetary stations, lunar latitude, lunar node
	• planetary visibility*
...	• (one folio missing?)
51–56	• *planetary visibility
	• trigonometry, declination and lunar latitude
?————	
57–63	• lunar eclipses by a method attributed to Yahyā
	• table of planetary stations
	• planetary latitudes, with tables
?————	
64–65	• solar declination and lunar latitude, with table
?————	
66–99	• tables for planetary mean motions and equations
	• trigonometry: sine table
?————	
31	• trigonometry: tangent table; fixed star table*
153–155	• *fixed star table, geographical table*

152	• *geographical table
	• lunar nodes, lunar eclipse circle*
———	
5–8	• *last two words of preceding section: *wa-kawākibihi*
	• year transfers
	• spherical astronomy: azimuth
	• world ascendant, year transfers
	• table for year transfers based on Ibn al-Aʿlam
	• time of a year transfer
?———	
9–12	• chronology: Christian feasts and fasts, with tables*
29–30	• *chronology: table for Christian feasts and fasts
	• lunar eclipses*
13–20	• *lunar eclipses, solar eclipses*
———	
111	• parallax table, solar eclipse table
?———	
32–33	• solar and lunar eclipse tables
?———	
110	• hourly motion of Sun and Moon, lunar crescent visibility*
36–44	• *lunar crescent visibility
	• lunar eclipses (Yaḥyā's method of *manzila*s), with tables
	• solar eclipses, with tables
	• year transfers, entry of Sun into signs, rising of Sirius*
112	• *rising of Sirius
	• chronology: conversion from Byzantine to Persian years
	• lunar crescent visibility: list of visibility limits
	• correction of the ascendant by the method of Vettius Valens*
21–22	• *correction of the ascendant, ascendant of the *qubba*
	• table of the apogee of Mars
	• two tables for the motion of the planetary apogees
?———	
23	• simplified method for oblique ascensions, with small tables
	• table for the duration of planetary stations, retrogradations, etc.
?———	
24–28	• year transfers according to al-Maʾmun, with table
	• right ascension table, table of the sine of the declination
	• conjunctions and oppositions
	• universal oblique ascension table*
———	

130	• *time of day or night, oblique ascensions*
...	• (one folio missing)
100–109	• spherical astronomy: various topics
	• right ascension table, oblique ascension tables*
4	• *oblique ascension table
	• shadow from altitude, time of night from fixed star*
3	• time of night, reference to tangent table, planetary rays
	• Hijra month beginnings (8-year cycle), with table
156–157	• chronology, in different hand

Note that there are five chapters in **L** for which I have not been able to find the beginning, four chapters for which I have not found a continuation, and one table whose second half is very probably missing (these can be recognized in the list above by asterisks immediately following or preceding definite breaks):

Chapters whose beginning has not been found in the manuscript:

3^r	timekeeping (time of night in seasonal and equal hours)
5^r	last two words of an unspecified chapter: *wa-kawākibihi*
51^r	planetary visibility (by means of calculation)
113^r	chronology (weekday of month beginning in unspecified calendar)
130^r	timekeeping (determination of the seasonal hours of daylight)

Chapters and one table whose end has not been found in the manuscript:

4^v	timekeeping (time of the night measured by a fixed star)
20^v	eclipses (determination of the ascendant for solar eclipse phases)
28^v	universal oblique ascension table (only latitudes 1 to 33° present)
35^v	planetary visibility (standard method by means of tables)
152^v	eclipses (lunar eclipses by means of the “eclipse circle”)

3 Contents of the Leipzig manuscript arranged by subject

A. Chronology

There are two longer sections on chronology in **L**, which are both part of the longest range of folios of which the original order can be reliably restored (see Section 2). These two sections were separated in the original manuscript by a number of completely different topics without any particular order or structure.

The first larger section on chronology (fols. 113–123v, incomplete at the beginning) gives a full treatment of the Arabic, Persian, Byzantine and Coptic calendars. It contains various of the chronological chapters that are also found in the first part of **E** (pp. 20–21, 6–10, 34–35). These include the *mujarrad* tables for the month beginnings in the Arabic, Byzantine and Persian calendars with instructions for their use. In his *Chronology*, al-Bīrūnī (973–1048, active in Khwarazm and Ghazna) attributes the *mujarrad* table for the Hijra calendar to Ḥabash al-Ḥāsib, but the table in **H**, fol. 86v, does not in fact carry that name (cf. Debarnot 1987, p. 41). **L** omits some of the most basic chapters in **E** giving the names and lengths of the months in the four calendars, but on the other hand includes topics missing from **E**, such as the method for calculating the Byzantine *aṣl* (number of days since epoch, cf. van Dalen 1998). **L** inserts an extensive extract (fols. 117r–121v) from chapter 32 of the *Ṣābiʾ Zīj* of al-Battānī without the corresponding tables. This section doubles much of the presumably original Mumtaḥan material, but is generally more thorough in its definitions and formulation of algorithms. Because in **E** the chronological material starts immediately after the introduction, and in **L** there is no introduction or beginning of the above chronological section, it is very well possible that folio 113r is the first folio of the original manuscript which is still extant. It is in fact more damaged than most of the other folios, as one might expect for the first sheet in a volume.

The second larger section on chronology in **L** (fols. 147r–151, 1–2, 34r) consists of explanations of the use of two tables for the conversion of dates expressed in seven different calendars and with respect to nine different epochs: the Flood, Nabonassar, Philippus, the Two-Horned (Alexander), August, Diocletian, Hijra, Yazdigird, and the not very commonly used epoch of the Abbasid caliph al-Muʿtaḍid, 11 June 895. A triangular table on fols. 151v, 1r displays for each of these epochs the day of the week at which they fell and the type of year (Persian, Byzantine, Arabic) with which they were used. Furthermore, for each pair of epochs the difference between them is expressed in Persian years and days and as total number of days (written in Hindu numerals). Since the latest epoch included in the table is that of al-Muʿtaḍid, and the epoch of Malikshāh (15 March 1079) is not yet mentioned, we may conclude that this table was very probably compiled in the tenth or eleventh century. In fact, it is very similar to that in al-Bīrūnī's *Chronology* (Sachau 1879, p. 133), which also ends with the epoch of al-Muʿtaḍid and additionally inserts the epoch of Antoninus. However, the eras of the Coptic calendar (August and Diocletian) are quite different between the two sources.[2]

2 The table in **L** implies the following dates for epochs that were not unambiguously defined

The triangular table is followed by another table (fols. 1^{v}–2^{v}, 34^{r}) that can be used for calendar conversions. This table displays the dates with respect to the epochs of the Flood, Nabonassar, Philippus, the Two-Horned, August, Diocletian and the Hijra which correspond to the beginnings of the collected Yazdigird years 1, 41, 81, ..., 801 (extended up to 1001 by a different hand in the margin), as well as the numbers of years and days in each of the calendars concerned that are equal to 1, 2, 3, ..., 40 Persian years and to each of the Persian months. Only for the Hijra calendar do the given values come with minutes and seconds of a day. A very similar table is found in the thirteenth-century zīj of Jamāl al-Dīn Abu 'l-Qāsim ibn Maḥfūẓ al-Baghdādī (MS Paris BNF arabe 2486, fols. 21^{v}–23^{v}), who, for many parts of his work, depended strongly on Ḥabash al-Ḥāsib and, for instance, also included the *mujarrad* tables mentioned above. The explanations for the use of the two conversion tables in **L** is highly repetitive and only explains the operations in general terms without giving any specific examples that might allow dating.

One more somewhat larger chronological section is found on fols. 9–12, 29^{r}, and consists of instructions for the determination of the Christian feasts and fasts with two extensive tables. The same material is found in **E**, pp. 141–148, and the tables also in the zīj of al-Baghdādī (MS Paris BNF arabe 2486, fols. 17^{r}–18^{v}, 14^{r}–15^{r}; the explanatory text on fols. 28^{v}–30^{r} is very different from that in **L** and **E**). The use of the tables has been explained in Saliba 1970, pp. 187–188, 193, 201–202. The method in **L** and **E** prescribes a substraction of 1204 from the Byzantine year, making it plausible that it was written down around the year AD 900.

Some more chronological material is scattered throughout **L**, and in one or two cases seems to have been used as filling material. An approximate method with table for finding the beginning of the Arabic months on the basis of an 8-year cycle is found on fol. 3^{v} (the explanatory text in **E**, pp. 11/119, is different). A very peculiar method for the conversion of Hijra years to Byzantine years (fol. 43^{v}; **E**, p. 12) involves the years of the *fatra* (period between the prophets Jesus and Muhammad), 612, and the years of the Seven Sleepers (*aṣḥāb al-kahf*), 307. The method boils down to adding a constant, 919, to the Hijra years, which led to correct results in the period from AD 1038 to 1068. Finally, a section on a standard conversion of Byzantine dates into Persian ones is hidden between chapters on the heliacal rising of Sirius and on lunar crescent visibility on fol. 112^{r}.

in medieval sources: Flood: Thursday, 17 February 3102 BC; August: Thursday, 13 November 30 BC; Diocletian: Thursday, 11 November 284.

B. Trigonometry

L contains relatively little material concerned with trigonometry. On fols. 52^{v}–54^{v}, there are five chapters giving definitions of the sine and the versed sine, which are illustrated by means of a diagram. Reference is made to a sine table with values for every degree up to ninety, and the use of this table for finding the sine and versed sines of a given arc and vice versa (by means of linear interpolation) is explained. These five sections, also contained in **H**, fols. 124^{v}–125^{r}, are followed by the basic spherical astronomical material discussed in section C. Immediately after the tables for the planetary equations, on fols. 98^{v}–99^{v}, there is another, differently worded section on the determination of sines and versed sines from tables (**E**, pp. 171–172), accompanied by a sine table with values to seconds for every degree for a radius of the base circle equal to 60. This table does not appear to be related to various other early Islamic sine tables that I have checked, and it is not directly derived from Ptolemy's table of chords either. The table has 38 errors, which are nearly all positive and are only incidentally larger than $1''$.

L includes a cotangent table with values to seconds for a gnomon length of 12 units (fol. 31^{r}), which immediately precedes the star table. This table appears to be related to the table in **E**, p. 120, but not to any other early Islamic tables that I have checked. Note that there is a reference to a tangent table for radius 60 on fol. 4^{v} (cf. section C), whereas al-Battānī's chapter on shadows and altitudes on fol. 135^{v} makes use of a cotangent table for gnomon length 12.

C. Spherical Astronomy and Timekeeping

L contains two larger sections dealing with spherical astronomical topics. The first of these (fols. 130, ..., 100–109, 4), incomplete at the beginning as well as at the end and with a lacuna in the middle, contains explanatory text and tables that are also found in **E**, pp. 162–168, 90–96. The lacuna can be assumed to consist of one folio covering the text in **E** from p. 164, line 7 to p. 165, line 19 (line 2 from the bottom of the page), all part of a chapter on oblique ascensions. The remaining text deals with the following topics: seasonal hours of day and night, oblique ascensions, half arc of daylight and seasonal hours, length of daylight, hour length, conversion of equal hours into seasonal hours, "sine of daylight", time of day from a measurement of the Sun, solar midday altitude, conversion of equal and ascensional degrees, ortive amplitude, ascendant, and the twelve houses. On fol. 130^{v}, it is said that the obliquity of the ecliptic, "according to what was found by Ibn al-Aʿlam, Yaḥyā ibn Abī Manṣūr al-Ḥāsib, and Abu 'l-Ḥasan al-Ṣūfī", was equal to 23°33′.

I have carried out brief mathematical investigations of the tables for right and oblique ascensions that follow the explanatory text.[3] The normed right ascension on fols. 103ʳ–104ʳ (**E**, pp. 93–94) is based on the Ptolemaic obliquity value 23°51′ and was calculated by applying so-called *distributed linear interpolation* (cf. Van Brummelen 1998, p. 278) between accurate values for every 10 degrees. The oblique ascension table for Baghdad (latitude 33°) on fols. 104ᵛ–106ʳ, accompanied by "parts of the hours", is *not* the same as that in **E**, pp. 95–97, which has tabular differences instead. In fact, the table in **L** turns out to be based on the Indian obliquity value 24°0′ and latitude 33°0′, whereas the table in **E** was computed for obliquity 23°35′ and the latitude value 33°25′ used by al-Nayrīzī and Abu 'l-Wafāʾ in the tenth century. An oblique ascension table for the latitude 36° of Raqqa (fols. 106ᵛ–108ʳ in **L**, pp. 90–92 in **E**) is basically identical with that in the *Ṣābiʾ Zīj* of al-Battānī. Finally, oblique ascension tables for the location of the compiler were added to both of the recensions extant as manuscripts **L** and **E**. In the case of **E**, this was Mosul, to which an unrealistically precise latitude 35°55′48″ was attached. The compiler of **L** added an oblique ascension table for "Mayyāfāriqīn, Āmid, Arzan, Badlīs, Khilāṭ (or: Akhlāṭ) and each locality whose latitude is 37°30′", and can hence be assumed to have lived in the region of Diyār Bakr in modern southeastern Turkey.

After the ascension tables (fol. 4ᵛ), **L** continues with a section on the determination of the shadow from a given solar altitude by means of a tangent (not cotangent!) table for radius 60. This table is not included in **L** but could very well be that on p. 105 in **E**, which is surrounded by tables that very probably stem from the original *Mumtaḥan Zīj* or another early Islamic source. Folio 4ᵛ in **L** ends with an incomplete section on the time of night from a measurement of a fixed star, which is different from **E**, pp. 185–186, and is *not* continued by the very similar text on fol. 3r.[4]

One would expect that the surviving section on spherical astronomy described above was preceded by chapters on the solar declination, right as-

[3] Here and elsewhere, parameters that are not explicitly said to be mentioned in the manuscript and that are not included in the titles of tables as listed in the Appendix were determined by the present author by means of the methods described in his doctoral thesis van Dalen 1993 and with the aid of his computer programs TA and MM.

[4] Folio 3 begins with the continuation of a chapter on the time of night expressed in seasonal and in equal hours, and then calculates the ascendant for the time found. Next follow a brief chapter on planetary rays (see section K below) and the approximate method for Hijra month beginnings based on an 8-year cycle (see above).

cension and equation of daylight, and possibly by chapters on trigonometry. However, the material dealing with these topics on fols. 52^{v}–56^{v} is of a very different nature, providing extensive definitions and methods of calculating the quantities as well as finding them from tables. The chapter on the solar declination on fols. 54^{v}–55^{r} presents the results of Ibn al-Aᶜlam's observations of the solar altitude at the solstices, leading to an obliquity of 23°33′ and a latitude for Baghdad of 33°21′.[5] The following chapters spell out the conditions for ascendance (*suᶜūd*) and descendance (*hubūṭ*) of the Sun and the Moon in detail. A table for the solar declination and lunar latitude on fols. 64^{v}–65^{v} (accompanied by instructions on fol. 64^{r}) is based on obliquity 23°35′ and maximum latitude 4°46′ and hence is not fully compatible with the above material, which involves three different early obliquity values but not the common 23°35′. The lunar latitude values are basically the same as those given together with the lunar equations in both **L** and **E**. We must thus conclude that the material originally preceding fol. 130 in **L** is lost.

The second larger section on spherical astronomy in **L** (fols. 133^{r}–141^{v}) is found in between longer sections on planetary visibility and on "applications" (*ittiṣālāt*). It deals with the following topics: solar declination (the obliquity is said to be 23°35′ "according to al-Battānī, Ḥabash al-Ḥāsib, Yaḥyā ibn Abī Manṣūr, and others"), right ascensions, altitude of the equatorial pole from the length of the longest day, increases in the length of daylight, calculation of altitude and shadow from each other, azimuth and shadow from altitude, local meridian, oblique ascensions, solar midday altitude. The chapters concerned run parallel to Chapters 4 to 15 of the *Ṣābiᵓ Zīj* of al-Battānī and also share with that work the use of chords for the calculations. Only one longer section entitled *Taṣnīf al-ᶜamal bi-l-maṭāliᶜ* (fols. 139^{r}–141^{r}) appears to derive from a different source. This rather elementary chapter describes the use of general sets of tables for the normed right ascension and the oblique ascensions of the climates for determining ascensions and their inverse, arcs of daylight and of nighttime, equal hours, seasonal hours of day and night, etc.

Further material in **L** on spherical astronomical topics is found on fols. 23^{r}–28^{v}. This section starts with a simplified method for calculating oblique ascensions by means of two small tables (to three sexagesimal places and based on obliquity 23°35′) for the right ascension and the sine of the right ascension for every 10 degrees of arc.[6] After a table for the duration of

[5] Exactly the same data are mentioned on the flyleaf of an early copy of the *Īlkhānī Zīj* by the famous polymath Naṣīr al-Dīn Ṭūsī (Maragha, ca. 1270); see King 2000, pp. 225–228, esp. footnote 55.

[6] These tables are identical with those on fol. 178^{r} of the Escorial manuscript of the zīj of

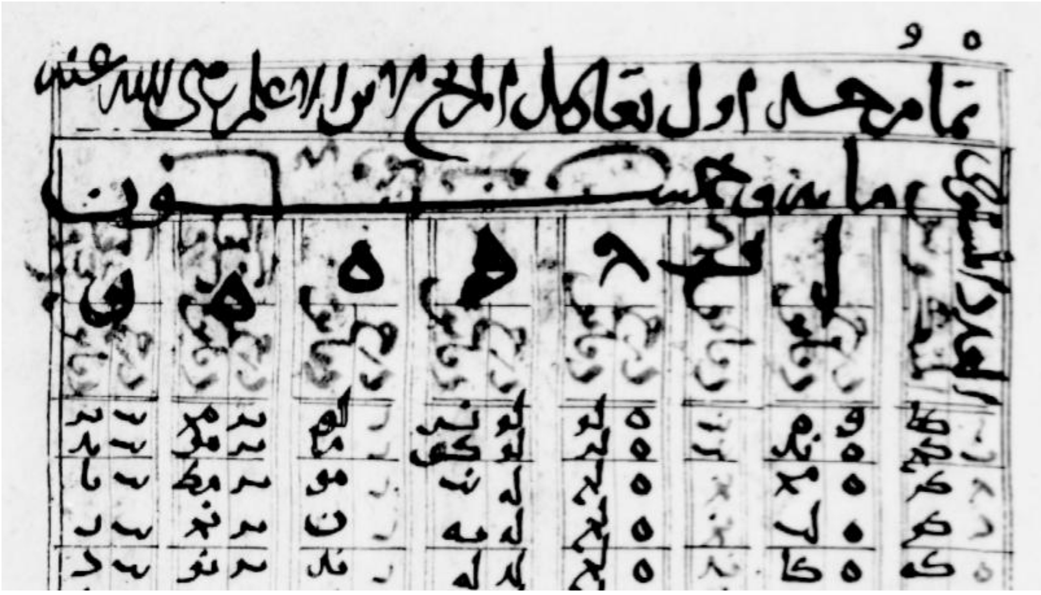

Figure 1: Table of equations for Mars, attributed to Ibn al-A^{c}lam (**L**, fol. 90$^{\mathrm{r}}$)
(reproduced with kind permission of the Universitätsbibliothek in Leipzig)

the planetary phases and one for year transfers attributed to Yaḥyā ibn Abī Manṣūr, fols. 25$^{\mathrm{v}}$–26$^{\mathrm{v}}$ present a table of right ascensions with values to seconds for every degree. This table is also found in **H**, fols. 132$^{\mathrm{v}}$–133$^{\mathrm{v}}$, and was computed for obliquity 23°35′ by means of linear interpolation between values for multiples of three degrees. However, the following highly accurate table for the tangent of the declination (*fuḍūl al-maṭali*^{c}, fol. 27$^{\mathrm{r}}$), a function that can be used for the easy computation of right ascensions and the equation of daylight, is based on obliquity 23°33′. This table is practically the same as that in MS Paris BNF arabe 2520, fol. 69$^{\mathrm{v}}$ (cf. King 2004, p. 151, Section 7.1.9). These two tables are followed by a chapter on conjunctions and oppositions that ends with the calculation of the ascendant for the time of a syzygy by means of a universal oblique ascension table; the first part of this table, based on the Indian obliquity value 24°, survives on fol. 28$^{\mathrm{v}}$.

D. Planetary longitudes

Fols. 66$^{\mathrm{r}}$–98$^{\mathrm{v}}$ of **L** contain the same set of tables for planetary mean motions and equations that is also found in **E**, pp. 25–31, 36–37, 32–33, 38–89,

al-Battānī. In Nallino 1899–1977, vol. 2, p. 58, various of the tabular values for the right ascension were corrected in ways that cannot be explained by ordinary scribal errors. I have not checked whether the explanatory text also occurs in the *Ṣābi*$^{\supset}$ *Zīj*. Similar data were already given by Ptolemy in the *Almagest*; cf. Neugebauer 1975, vol. 2, pp. 980–982. References to these two secondary sources are contained in King 2004, p. 152, Section 7.2.

including the equations for Mars attributed to Ibn Aᶜlam (see Figure 1). The tabular values are in most cases identical, the two manuscripts sometimes having scribal errors in common, but also having their individual ones. The shifts of whole columns of digits which are rather common in the mean motion tables in **E** are not found in **L**. We conclude that the two sets of tables are based on a common predecessor.

The mean motion tables in the two manuscripts, laid out for the Persian calendar and presenting positions for the Yazdigird years 1, 21, 41, ..., 601, can be compared with some data for Yaḥyā ibn Abī Manṣūr given by Ibn Yūnus (Cairo, ca. 1000) in the *Ḥākimī Zīj*, which is partially extant in Leiden and Oxford (Caussin de Perceval 1804, pp. 216–221). They turn out to agree in each case except for Mars. It thus seems probable that for Mars not only the equations but also the mean motions of Ibn al-Aᶜlam are given in **L** and **E**. Note that the mean motion tables for Mars in both manuscripts have values to seconds only, whereas the tables for all other planets have values to thirds. Furthermore, in **E** the equations for Mars come without the columns for the first and second station which are present for all the other planets; in **L** these stations were apparently added (see also section F below). Nevertheless, the equations for Mars in **L** and **E** are all basically the same as found in the *Handy Tables*, which would mean that Ibn al-Aᶜlam only made significant modifications to the mean motions for this planet.[7] The mean motion parameters for Mars attributed to Ibn al-Aᶜlam in **L** (fol. 61ʳ) as well as in **E** (p. 67, in an empty space of the mean motion table) are in full agreement with the tables in the two manuscripts.

The solar equation in **L** is basically identical with that in **E**, and hence does not contain the errors spotted by Ibn Yūnus in the solar equation in the

[7] The *Ashrafī Zīj*, compiled in the early fourteenth century by Sayf-i munajjim-i Yazdī and extant in the unique MS Paris BNF suppl. persane 1488/1, gives the elements of planetary motion for more than ten different zījes, including the one by Ibn al-Aᶜlam. From the fact that for Ibn al-Aᶜlam only the solar equation, the lunar equation of anomaly, and the equation of centrum for Saturn, Jupiter and Venus are presented, we may conclude that his equations for Mars were basically the same as those in the *Handy Tables*. The earliest documented change of one of the equations for Mars by a Muslim astronomer is that of the equation of centrum by Kūshyār ibn Labbān (ca. AD 1000; cf. Van Brummelen 1998, pp. 268). The mean motion in longitude that is associated with Ibn al-Aᶜlam in the *Ashrafī Zīj* is in almost perfect agreement with the tables for Mars in **L** and **E**; for the mean motion in anomaly there is a small deviation.
The planetary parameters from Ibn al-Aᶜlam's zīj were reconstructed from various sources in Kennedy 1977 and Mercier 1989. To the results it may be added that the mean motion tables for Mars in **L** and **E** are fully compatible with the table for the Hijra calendar in the zīj of al-Baghdādī (MS Paris BNF arabe 2486, fols. 85ᵛ–86ʳ). Byzantine materials related to Ibn al-Aᶜlam were studied in Tihon 1989.

Mumtaḥan Zīj, which are in fact present in the zīj of Ḥabash al-Ḥāsib (**H**, fols. 90ʳ–91ʳ). The longitudes of the solar and planetary apogees mentioned in the titles of the equation tables in **L** are the same as those in **E** and agree with the values mentioned by Ibn Yūnus, except for Mars, for which **L** gives an apogee longitude of 128°50′, whereas Ibn Yūnus attributes to Yaḥyā ibn Abī Manṣūr the value 124°33′ (Caussin de Perceval 1804, pp. 220–221). This very value is indeed found in the list of apogee longitudes on fols. 60ᵛ–61ʳ of **L**.[8] It is reasonable to assume that the table for the apogee of Mars on fol. 21ᵛ, immediately preceding the table for apogee motion based on Ibn al-Aᶜlam's parameter of 1° in 70 Persian years and also itself computed for this value, displays the apogee longitudes according to Ibn al-Aᶜlam. This table displays the longitude given with the equation table for the year 180 Yazdigird (AD 811), around 20 years too early for Yaḥyā. Its values are also in relatively good (but not perfect) agreement with those in the *Ashrafī Zīj*.[9] Note that **L**, fol. 22ᵛ, also includes a table for apogee motion based on the parameter of "al-Battānī and al-Maʾmūn", 1° in 66 Julian years.

The instructions for the use of the tables for mean motions and equations (**L**, fols. 47ᵛ–50ᵛ; **E**, pp. 157–159) are in concordance with the tables. From **E**, the instructions for finding the mean motions and the true solar longitude are missing. In neither manuscript are the instructions found in the direct vicinity of the planetary tables. On fols. 124ʳ–124ᵛ of **L** we find two inconsequential fragments on mean motions in anomaly (similar to **H**, fol. 102ᵛ) and a brief section on the equation of time (involving a constant also used by Ḥabash; cf. Debarnot 1987, p. 42) in between a chapter on retrogradation and a general introduction to astronomy attributed to al-Battānī.

E. Planetary Latitudes

The only section on the latitudes of the five planets in **L** appears on fols. 60ᵛ–63ᵛ. It starts immediately after the tables for the planetary stations (see below) with a brief explanation of the determination of planetary latitudes according to "the method of Ptolemy, simplified". The procedure described

8 It can be noted that the equation tables of Ḥabash mention the same apogee longitudes as the *Mumtaḥan Zīj* except for Saturn (242°50′ vs. 244°30′; see **H**, fols. 89ʳ, 103ʳ, 107ʳ, 111ʳ, 115ʳ, and 119ʳ).

9 Cf. footnote 7. Interestingly enough, the epoch value of the table for the apogee of Mars in **L** is the same as that given on fols. 2ʳ–2ᵛ of the unique MS Paris BNF arabe 5968 of an eleventh-century Ismāᶜīlī zīj called *Dastūr al-munajjimīn*. On the other hand, the apogee longitude of Mars given for the Hijra epoch in the *Baghdādī Zīj* (fol. 42ᵛ) does not appear to be reconcilable with any of the other surviving values.

yields the planetary latitude directly from a single table as a function of the distance between the planet and one of the nodes. A similar method is found on **E**, p. 115, except that there for the inferior planets the node is subtracted from *al-ḥiṣṣa al-thāniya*, presumably the true anomaly. As has been shown in Viladrich 1988, the latitude tables in **E**, pp. 109–114, are sinusoidal functions, for which the underlying maximum values were taken from the *Handy Tables*. In **L**, the tables are even simpler because, different from **E**, the northern and southern latitudes for the superior planets are basically identical. The maximum latitudes of the five planets are: Saturn 5°0′, Jupiter 2°0′, Mars 3°45′, Venus 2°26′, Mercury 2°28′. For Saturn and Mars these maxima happen to be identical with those of the second latitude as given by al-Khwārizmī (cf. Suter 1914, pp. 138–167; the tables as such are *not* identical), but in general the origin of the latitude tables in **L** is completely unclear to me. The following longitudes of the planetary nodes, given together with the instructions (fol. 60ᵛ, lines 6–11, repeated in lines 11–15), might very well be corrupt: Saturn 120°, Jupiter 80°, Mars 60°, Venus 40°, Mercury 20°.

The planetary latitude tables are immediately followed by a combined table for the solar declination for obliquity 23°35′ and the lunar latitude with maximum 4°46′, accompanied by instructions for its use (fols. 64ʳ–65ᵛ). The lunar latitude is basically identical with that found in the last column of the table for the lunar equations, whereas the solar declination (calculated by means of interpolation on intervals of 6 degrees) is less accurate than all other declination tables surviving from the early Islamic period. It is remarkable, in particular, that the combined solar declination and lunar latitude table in the zīj of Ḥabash al-Ḥāsib (**H**, fols. 99ʳ–100ʳ), based on the same parameters, is clearly different from the table in **L**.

There are scattered other sections concerning lunar latitudes in **L**. On fols. 35ʳ–35ᵛ, chapters on finding the lunar latitude and the true longitude of the node from tables are embedded between texts on planetary stations and planetary visibility. On fols. 55ᵛ–56ʳ, the solar declination and lunar latitude are found by calculation and from a combined table involving a maximum lunar latitude of 5°0′. On fols. 129ᵛ, 131ʳ, the lunar latitude is found from the seventh column of the table for the lunar equations; hence this chapter, surrounded by longer texts on general principles of almanacs and planetary visibility (see sections L and G below), may very well be from the original *Mumtaḥan Zīj*. Finally, on fol. 152ᵛ, following the geographical table and preceding the chapter on the use of the eclipse circle (see section H), there is a trivial chapter on finding the positions of the lunar nodes.

F. Planetary stations

A set of tables for the first stations of the five planets occurs on fols. 57v–60r of **L** in between a simple method for lunar eclipses attributed to Yaḥyā ibn Abī Manṣūr and non-Ptolemaic material on planetary latitudes. For each planet, the values in these tables are basically identical with those from Ptolemy's *Handy Tables*, which were also adopted by al-Battānī in his *Ṣābiʾ Zīj*. (In contrast, Ḥabash al-Ḥāsib included the first stations as found in the *Almagest*, which were tabulated as a function of a different argument.) The tables for the stations that are included with the planetary equations in **L** (fols. 77v–98r) are basically the same as the separate tables, except for Mars, for which the tabulated stations are completely different from Ptolemy or any known early Islamic sources (note that **E** does not include the stations for Mars at all). It seems possible that the compiler of the recension in **L** added the stations from the zīj of Ibn al-Aʿlam to the latter's equations for Mars.

There is scattered other material related to planetary stations in **L**. A table on fol. 23v displays for each of the five planets the duration (in days and minutes of a day) of their direct motion, first station, retrograde motion, second station, again direct motion, and the sum of these five quantities. Standard instructions for the use of tables for the stations are found on fols. 50v, 35r (here explicit reference is made to columns for the first and for the second station, probably those in the tables for the planetary equations), and on fols. 123v–124r (here the second station is found as 360° minus the first station).

G. Lunar and Planetary Visibility

Two methods for determining the visibility of the lunar crescent after new moon are given on fols. 110r–110v, 36r in **L**. They appear to differ in their details from other known early methods, but are clearly based on the Indian criterion, which lets the visibility depend on the difference in setting time between the Sun and the Moon. The only other material on lunar crescent visibility in **L** is a list of visibility limits for the twelve zodiacal signs on fols. 112r–112v. This list also occurs in **E**, p. 12, and is discussed in King 1987, pp. 213–214.

L contains an extensive section on the visibility of the planets on fols. 131r–133r. This starts by giving definitions and some simple criteria for visibility. It then presents a "more correct" method that involves the following arcs of visibility: Saturn 14°0′, Jupiter 12°45′, Mars 14°30′, Venus 5°40′, Mercury 11°30′. For the calculation of the difference in setting time between the Sun and the planet, taking the latter's latitude into account, reference is made to a chapter on lunar crescent visibility. The text continues with a method for finding the number of days that have passed since, or will elapse until, a first or last visibility, and ends with instructions for determining the visibility of a planet from the table for the fourth climate in the *Almagest*.

A set of standard planetary visibility tables is present on fols. 51^{v}–52^{r} in **L**. The instructions for their use start on fol. 35^{v}, which ends with taking a tabular value for the zodiacal sign of the planet, and continue after a lacuna on fol. 51^{r} with the calculation of the time of first or last visibility using the difference between solar and planetary velocity. Further information on planetary visibility in Islamic sources can be found in Kennedy & Agha 1960.

H. Eclipses

L contains various sections on solar and lunar eclipses, not all of which are also included in **E**. The method (fols. 40^{v}–41^{r}) of calculating solar eclipses by means of tables for *al-samt* (fols. 41^{v}–42^{r}) and *ᶜarḍ al-shams* (fol. 42^{v}) as well as a solar eclipse table as a function of *ᶜarḍ al-qamar al-muḥkam* (fol. 43^{r}), is also found in **E** (pp. 15–17, 19/138, 22–24). In Kennedy & Faris 1970, p. 20, the association of this material with Yaḥyā ibn Abī Manṣūr was established. The explanatory text in **L** does not mention the geographical latitude 35°55′48″, which also occurs elsewhere in **E** in connection with the city of Mosul, but it appears to be more complete than the version in **E** and might hence help to solve the few remaining problems in the method.

In **L**, the method above is preceded by an unusual method for calculating lunar eclipses (fols. 36^{r}–40^{v}), which is associated in the text with Yaḥyā ibn Abī Manṣūr and Ḥabash al-Ḥāsib and is not contained in **E**. Depending on the value of the true lunar anomaly, the magnitude and duration of the eclipse and, if applicable, the duration of totality are taken from one of six similar tables, called the first to six *manzila* (not to be confused with the lunar mansions). For higher accuracy, minutes given together with the *manzila*s as a function of the true anomaly allow the performance of linear interpolation between the six tables. A brief section on the colours of lunar eclipses, similar to that on pp. 14/171 of **E**, has been added to the explanatory text on fol. 36^{v}.

Both **L** (fol. 57^{r}) and **E** (p. 14) include a simple method for the calculation of lunar eclipses that is associated with Yaḥyā ibn Abī Manṣūr and involves three small tables headed *al-bāb al-awwal* (magnitude as a function of the lunar distance from a node), *al-bāb al-thānī* (duration of the eclipse as a function of the magnitude), and *al-bāb al-thālith* (duration of totality as a function of the magnitude).

Fols. 29ᵛ–30, 13–20 of **L** contain another extensive set of instructions for calculating lunar and solar eclipses, incomplete at the end. They have the peculiar characteristic that the ascendant and upper midheaven are explicitly calculated for each of the phases of the eclipse that are found. The following tables in **L** are associated with the method for lunar eclipses presented in this section: eclipse tables for nearest and farthest distance with argument columns for the distance of the moon from the node numbered "1" to "4" as well as columns for the magnitude and duration (fols. 32^{v}–33^{r}); and an eclipse equation as a function of the true anomaly (fol. 33^{v}). The following tables are associated with the method for solar eclipses presented in this section: lunar parallax (fol. 111^{r}); latitude component of lunar parallax (*ikhtilāf ʿarḍ al-qamar li-l-ruʾya*, fol. 32^{r}, **E** p. 137);[10] an eclipse table as a function of *ʿarḍ al-qamar al-muḥkam* (fol. 111^{v}), and the eclipse equation also used for lunar eclipses (fol. 33^{v}). The section on conjunctions and oppositions (fols. 27^{v}–28^{r}; **E**, pp. 159–161), which also ends with the determination of the ascendant and upper midheaven (using a small universal table of oblique ascensions, only partially extant for latitudes 1° to 33°) can be assumed to be from the same source as the eclipse material mentioned above.

Another interesting, incomplete section on lunar eclipses occurs on fol. 152^{v}. It gives instructions for drawing the configuration of an eclipse by means of an "eclipse circle" (*dāʾirat al-kusūf*). The complete text is available in **H**, fols. 205^{v}–206^{r}. I have not been able to piece together the remaining texts and tables in **L** related to eclipses: a small section on the hourly motion of the Sun and Moon (fol. 110^{r}; **E**, pp. 9/16), a simplified method for lunar eclipses referring to a table that has the lunar latitude as argument (fol. 43^{v}), and a solar eclipse table as a function of the distance between moon and node (fol. 44^{r}). The only eclipse material in **E** not contained in **L** is a theoretical treatise on pp. 176–179.

I. Fixed stars

L contains on fols. 31^{v}, 153^{r} the table with ecliptical and equatorial positions of 18 fixed stars for the year 380 Yazdigird (AD 1011) that is also found in **E**, pp. 189–190. As has been shown in Girke 1988, the ecliptical coordinates in this table are based on those in the table of 24 stars said to be derived from the Mumtaḥan observations at Baghdad in 214 Hijra (AD 829), likewise extant

[10] The same table is found in the extant Latin recension of the zīj of al-Khwārizmī; see Suter 1914, pp. 191–192 and Neugebauer 1962, pp. 121–123. For a general description of Yaḥyā ibn Abī Manṣūr's parallax theory, see Kennedy 1956b, pp. 44–46.

in **E**, p. 188, but in a later hand. Note that the *Īlkhānī Zīj* of Naṣīr al-Dīn al-Ṭūsī attributes coordinates for the same 18 stars, derived from the table in **L** and **E**, to Ibn al-Aʿlam (cf. Kunitzsch 1964, pp. 397–398).

Besides the star table, the only other material in **L** dealing specifically with fixed stars is a chapter on the rising of Sirius (fols. 44^v, 112^r), which gives the date, the time of day or night and the ascendant for the moment of the heliacal rising as a function of the remainder of the division of the incomplete Byzantine years plus six by four. The date of rising is either 19 or 20 July.

J. Geography

L contains a table of geographical coordinates for 180 localities said to be taken from *Kitāb Ṣūrat al-arḍ* (fols. 153^r–155^v, 152^r). Given the early Islamic character of much of the material in the manuscript, one might expect that this title refers to the book by Muḥammad ibn Mūsā al-Khwārizmī (edited in von Mžik 1926), or to the work by the geographers of al-Maʾmūn in general (cf. Sezgin 2000, vol. 10, chapter I-D and p. 148). A first investigation of the table reveals that its direct source is most likely the geographical table in al-Battānī's *Ṣābiʾ Zīj* (Nallino 1899–1907, vol. 2, pp. 33–54 (edition) and vol. 3, pp. 234–241 (Arabic)), whose title includes both the "awsāṭ al-buldān" ("centres of the regions") and the *Kitāb Ṣūrat al-arḍ* that are also mentioned in the title of the table in **L**. In fact, basically all localities and regions listed in **L** are also found with al-Battānī and most of the differences in coordinates are due to copying mistakes. The data for Baghdad, Raqqa and Harran are indicated to have been "verified" (*mumtaḥan*), as in the *Ṣābiʾ Zīj*. However, the localities in **L** occur in a haphazard order and only incidentally include consecutive stretches in the same order as found in the zīj. In three or four cases columns of degrees or minutes of one of the coordinates were shifted, resulting in nonsensical data. For some localities coordinates in **L** different from al-Battānī's are identical with those in the work on the qibla by the 13th-century Egyptian scholar Zayn al-Dīn al-Dimyāṭī (QBL in Kennedy & Kennedy 1987, pp. 443–448), but this latter source does not include the coordinates for a large number of regions, which are typical for al-Battānī.

K. Astrology

Fols. 24^v–25^r of **L** display an eternal table for finding year transfers, which is attributed to al-Maʾmūn (see Figure 2). The table in fact gives the ascendant of the year transfer as a function of that for the previous year. It is preceded

Figure 2: Table of year transfers associated with al-Maʾmūn (**L**, fol. 24v)
(reproduced with kind permission of the Universitätsbibliothek in Leipzig)

by instructions, which mention the excess of revolution as 86°45′, and a brief section on determining the transfer of the world year.

On fol. 44v, following a set of eclipse tables, there is a somewhat isolated chapter on finding the ascension of the year transfer from a given ascendant. The excess of revolution here given in words, 86°43′39″, underlies a table for the same purpose on **E**, p. 142. This chapter is followed by a list of the solar mean positions corresponding to the entry of the true Sun in the zodiacal signs. Like most of these lists, the values are not particularly accurate (cf. Viladrich 1996), but they correspond reasonably well to the Maʾmūnic apogee longitude 82°39′ and an eccentricity (not maximum equation!) of 1;59p.

A third, larger section on year transfers is found on fols. 5r–8r. At first (fols. 5r–5v), the transfer of the world year, i.e., the time of the true vernal equinox, is found by calculating the solar longitude at noon of the day on which the equinox occurs and then correcting for the difference between this longitude and 0° Aries, if desired by means of an iterative procedure. On fols. 5v–6v, the use of the table on fols. 7v–8r for calculating the transfers of nativities and world years is explained. This table, said to be according to the observations of Ibn al-Aʿlam, displays the difference in the ascension of the ascendant (*faḍl al-ṭāliʿ*) and in the date and time of the transfer (*faḍl al-taʾrīkh*) for 1 to 90 years. The underlying excess of revolution, slightly less than 87°13′, can be read directly from the table. This value is highly accurate and, as far as I know, hitherto unattested.

The above material is interspersed with chapters of a more spherical astronomical character: on the calculation of the azimuth from the altitude and the ascendant (fols. 6^{v}–7^{r}), of the "ascendant of the world" or "centre of the earth" from the ascendant of the world year at Baghdad (fol. 7^{r}), and of the time of day or night (*dāʾir min al-falak*) of a year transfer at Baghdad and other localities (fol. 8^{v}). A small chapter (fol. 7^{r}) on finding the transfer of world years is identical with that on fol. 24^{r}.

A long chapter on *ittiṣālāt* ("applications", various types of relative positions of the planets in longitude and latitude) on fols. 141^{v}–144^{r} of **L** deals with aspects and rays adjusted for latitudes and with nativity *tasyīr*s. It has a similar title and is concerned with similar topics as Chapter 54 of the *Ṣābiʾ Zīj*, although the two texts do not seem to be identical.

On fol. 3^{r} of **L** there is a brief chapter on the projection of the rays according to an author whose name is written as "Drīnūsh". This is very probably Dorotheus, normally rendered in Arabic as Dhūruthiyūs, one of the most important Greek authorities for early Muslim astrologers (see, for instance, Sezgin 1979, pp. 32–38, and the supplement volume of the *Dictionary of Scientific Biography*). The method described is based on right ascensions and therewith of a type usually associated with pre-Islamic Iranian astrology. On fols. 112^{v}, 21^{r}–21^{v} a section entitled "Chapter of *namūdhār*s" describes the correction of the time of a nativity by means of the method of Wālīs (Vettius Valens). This is followed on fol. 21^{v} by a brief chapter on the "ascendant of the *qubba*" (cupola, central meridian of the world), which is calculated by adding twenty degrees to the oblique ascension of the ascendant of the world year at Baghdad and then taking the inverse right ascension.[11]

L. Various

This section lists the few remaining sections and tables that do not fit so easily in one of the preceding categories. On fol. 123^{v} of **L**, between the first larger section on chronology and a chapter on retrogradations, there is a small section on linear interpolation between two values from a table for an equation (*taʿdīl daqāʾiq al-ḥiṣṣa*, "the equation for minutes of the argument"). A treatise on a sundial for seasonal hours on fols. 144^{r}–147^{r} is similar to Chapter 56 of the *Ṣābiʾ Zīj*.

A chapter without title but with a lacuna (fols. 124^{v}–125, ..., 126–128^{r}),

[11] Since the centre of the world is given a longitude of 90°, this method implies a longitude for Baghdad of 70°, as found with al-Khwārizmī, rather than 80° as in the zīj of al-Battānī and the geographical table in **L**.

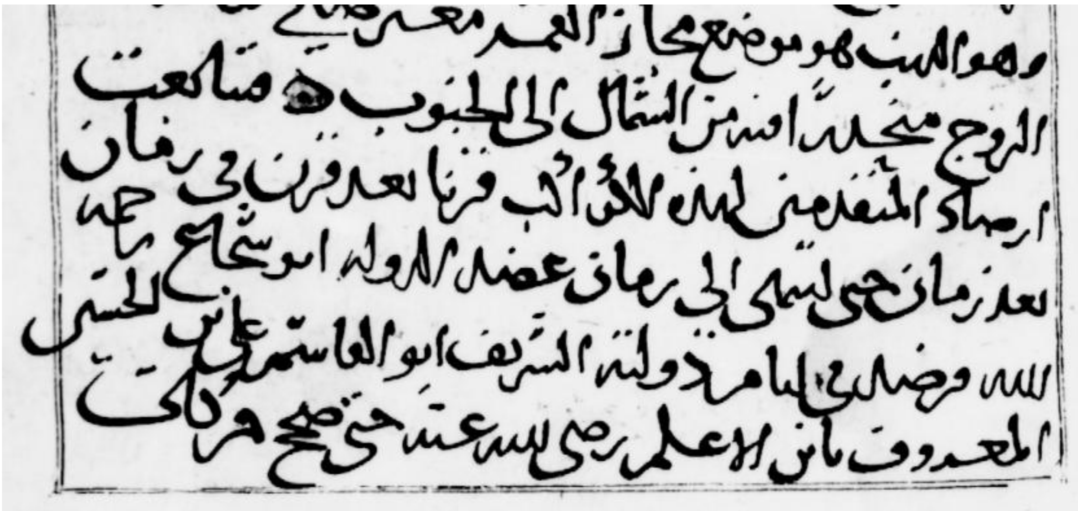

Figure 3a: First part of section mentioning the "Maʾmūnic Zīj" (**L**, fol. 47^{r}, bottom)
(reproduced with kind permission of the Universitätsbibliothek in Leipzig)

associated with al-Battānī, deals with the five basic great circles on the heavenly sphere (giving the obliquity of the ecliptic as 23°35′), the division of the ecliptic into signs and degrees, the division of degrees into minutes, seconds, thirds, etc., and the results of multiplying or dividing such divisions. The contents is similar to Chapter 2 of al-Battānī's *Ṣābiʾ Zīj*, but the wording clearly different. This section is followed by a chapter on laying out almanacs (fols. 128^{r}–129^{v}), explaining how to make entries for consecutive days and hours, convert equal hours to seasonal hours and mean time to true time, and calculate the mean solar longitude for the resulting times. The tables used are said to be for Baghdad, with latitude 33°.

A chapter on the conditions (*aḥwāl*) of the planets on fols. 34^{v}, 45–47^{v}, immediately after the chronological section to which it also refers and preceding the main section on the determination of planetary positions, gives another general introduction to astronomy, discussing the shape of the earth and the heavens, the zodiac and its subdivisions (with a list of the Arabic and Greek names of the signs), and the planets and their motions and spheres (with mention of the Arabic, Persian and Greek names of the planets). This section ends by stating that observations of the planets had been performed over and over again up to the time of ʿAḍud al-Dawla (936–983), under whose rule Ibn al-Aʿlam corrected the motions of the Sun, Moon and planets. Since "the Mars of Ibn al-Aʿlam ... is the best of the Marses in all zījes", it was included in "this corrected Maʾmūnic zīj" (*hādha ʾl-Zīj al-Maʾmūni ʾl-muṣlaḥ*; fol. 47^{v}, line 2; see Figures 3a and 3b).

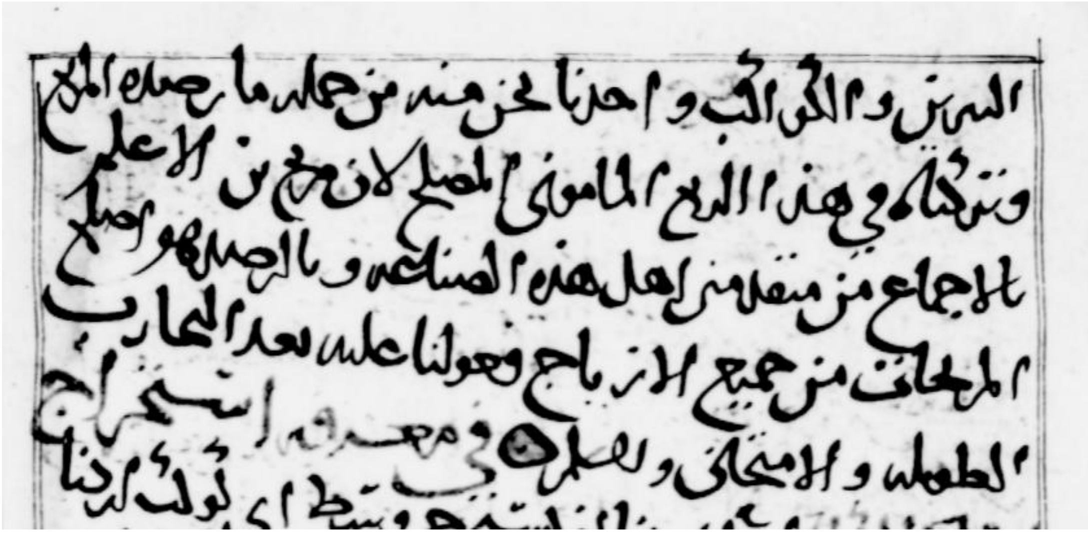

Figure 3b: Last part of section mentioning the "Maʾmūnic Zīj" (**L**, fol. 47^{v}, top)
(reproduced with kind permission of the Universitätsbibliothek in Leipzig)

Summary

From the above overview of the contents of **L**, we can see that the following materials are explicitly attributed to early Muslim astronomers:

- al-Maʾmūn: eternal table for year transfers with instructions (fols. 24^{r}–25^{r}), value for apogee motion underlying the table on fol. 22^{v};
- Yaḥyā ibn Abī Manṣūr: a simple method for lunar eclipses (fols. 57^{r}), the *manzila* method for lunar eclipses (fols. 36^{r}–40^{v});
- Ḥabash al-Ḥāsib: the *manzila* method for lunar eclipses (fols. 36^{r}–40^{v});
- al-Battānī: general introduction on great circles, divisions of the ecliptic, and multiplication and division of parts of degrees (fols. 124^{v}–128^{r}), section on chronology (folios 117^{r}–121^{v}), value for apogee motion underlying the table on fol. 22^{v};
- Ibn al-Aʿlam: value for apogee motion underlying the table on fol. 22^{r}, list of mean motion parameters for Mars (fol. 61^{r}), equations (and stations?) for Mars (fols. 87^{v}–90^{r}), table for year transfers (fols. 5^{v}–6^{v}, 7^{v}–8^{r}).

Other materials in **L** that can be assumed to derive from the original *Mumtaḥan Zīj*, partially because they are also found in **E**, include the sections on chronology (fols. 113–123^{v}) and spherical astronomy (fols. 130, ..., 100–109, 4), the material on solar eclipses (fols. 40^{v}–43^{r}), and the instructions for finding lunar latitudes (fols. 129^{v}, 131^{r}) and stations (fols. 50^{v}, 35^{r}) from tables. Judging from the underlying values for the obliquity of the ecliptic, also the tables for the tangent of the declination (fol. 27^{r}), the normed right ascension (fols. 103^{r}–104^{r}; **E**, pp. 93–94), the oblique ascension for Baghdad (fols. 104^{v}–106^{r}), and the oblique ascension for all latitudes (fol. 28^{v}) can be assumed to stem from the ninth century.

By a direct comparison, some more chapters in **L** can be seen to derive from the zījes of Ḥabash al-Ḥāsib and al-Battānī. The sections on the sine and versed sine (fols. 52^{v}–54^{v}) and on the lunar eclipse circle (fol. 152^{v}) are also contained in the Istanbul manuscript of the zīj of Ḥabash. The consecutive sections on spherical astronomy (fols. 133^{r}–139^{r}, 141^{r}–141^{v}), "applications" (*ittiṣālāt*, fols. 141^{v}–144^{r}), and the construction of a sundial for seasonal hours (fols. 144^{r}–147^{r}) are similar to chapters in al-Battānī's *Ṣābiʾ Zīj*.[12] Furthermore, the table for the oblique ascension at Raqqa (fols. 106^{v}–108^{r}) and the geographical table (fols. 153^{r}–155^{v}, 152^{r}) are clearly related to the corresponding tables in the *Ṣābiʾ Zīj*. As far as Ibn al-Aʿlam is concerned, not only the equations but also the mean motions for Mars (fols. 85^{v}–87^{r}) can be attributed to him.

We have seen that the manuscripts **L** and **E** have the following materials in common:

- large part of the chronological section on fols. 113–123^{v} (except for an extract from al-Battānī's *Ṣābiʾ Zīj* on fols. 117^{r}–121^{v});
- text and tables for finding the Christian feast and fasts;
- table for the 8-year cycle of the Hijra calendar;
- method for converting from the Arabic to the Byzantine calendar by means of the years of the *fatra* and the Seven Sleepers;
- a chapter on finding sines and arcsines from a table of sines;
- a cotangent table for gnomon length 12;
- largest part of the spherical astronomical section on fols. 130, 100–109, 4;
- spherical astronomical tables: normed right ascension, oblique ascension for Raqqa;
- tables for solar, lunar and planetary mean motions and equations, including the tables for Mars taken from Ibn al-Aʿlam;
- a list of mean motion parameters for Mars associated with Ibn al-Aʿlam;
- chapters on the true lunar and planetary positions;
- a listing of visibility limits for the lunar crescent;
- a chapter on solar and lunar conjunctions and oppositions;
- an isolated section on the hourly motion of Sun and Moon;

[12] I have not compared these sections in detail with Nallino's edition; more often than not the texts appear to be so different that one might consider the possibility that they come from a different source in spite of obvious similarities. In particular, it might be possible that they stem from the earlier edition of al-Battānī's zīj which is mentioned in the *Fihrist* by Ibn al-Nadīm (AD 987).

- a simple method for lunar eclipses attributed to Yaḥyā ibn Abī Manṣūr;
- a brief section on the colour of lunar eclipses;
- text and tables on solar eclipses associated with Yaḥyā ibn Abī Manṣūr;
- a table for the latitude component of lunar parallax;
- a table with coordinates and other data for 18 stars for the year 380 Yazdigird;
- a chapter describing the *namūdhār* of Vettius Valens.

Both manuscripts also include tables for the solar declination / lunar latitude, for the ordinary (as opposed to: normed) right ascension, for the oblique ascension at Baghdad and at the locality of the compiler, and for planetary latitudes, but the parameters underlying these tables are different between the two sources.

Material found in **L** but not in **E** includes:

- two tables for the conversion of dates with explanatory text;
- universal oblique ascension table based on the Indian obliquity value 24°;
- accurate table for the tangent of the declination based on obliquity 23°33′;
- tables of apogee motions and positions for Mars according to Ibn al-Aᶜlam;
- separate tables for planetary stations, and a theoretical text on this topic;
- two methods for determining the visibility of the lunar crescent;
- tables for planetary visibility with instructions;
- *manzila* tables for lunar eclipses associated with Yaḥyā and Ḥabash;
- chapter on the time of the heliacal rising of Sirius;
- geographical table related to that of al-Battānī in the *Ṣābiᵓ Zīj*;
- table for year transfers attributed to al-Maᵓmūn;
- table for year transfers based on Ibn al-Aᶜlam.

Material found in **E** but not in **L** includes:

- tables of Abu 'l-Wafāᵓ and Kūshyār ibn Labbān;
- section on the Jewish calendar (discussed in Vernet 1954);
- tangent table with values to seconds for radius 60;
- further topics in spherical astronomy;
- three sections on the latitude of the visible climate, with tables;
- some chapters on the size of the planetary spheres;
- star table for AD 829 associated with the Mumtaḥan observations;
- different methods for the projection of the rays;
- various sections on astrological indicators.

A comparison with **L** makes it easier to restore the order of the first forty pages in **E** (the remainder of the manuscript appears be in correct order; note that each odd-numbered page in the facsimile is the obverse of the next *lower* even page, so that, for instance, pages 4–5 constitute one folio): 3–5, 20–21, 6–7, 8–9, 34–35, 10–31, 36–37, 32–33, 38–89 (pp. 65–66 contain spherical astronomical tables for latitude 36° that do not normally belong in between the planetary tables).

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Bibliography

Caussin de Perceval, Jean-Jacques-Antoine 1804. "Le livre de la grande table hakémite, Observée par le Sheikh, ..., ebn Iounis", *Notices et Extraits des Manuscrits de la Bibliothèque nationale* **7**, pp. 16–240 (references are to the separatum, which has page numbers 1–224).

van Dalen, Benno 1993. *Ancient and Mediaeval Astronomical tables: mathematical structure and parameter values* (doctoral thesis), Utrecht (Mathematisch Instituut).

—— 1998. "Taʾrīkh I-2. Era chronology in astronomical handbooks", in: *The Encyclopaedia of Islam. New edition*, Leiden (Brill), vol. 10, pp. 264–271.

Debarnot, Marie-Thérèse 1987. "The *Zīj* of Ḥabash al-Ḥāsib: A Survey of MS Istanbul Yeni Cami 784/2", in: King & Saliba 1987, pp. 35–69.

Girke, Dorothea 1988. *Drei Beiträge zu den frühesten islamischen Sternkatalogen. Mit besonderer Rücksicht auf Hilfsfunktionen für die Zeitrechnung bei Nacht*, Preprint Series No. 8, Frankfurt am Main (Institut für Geschichte der Naturwissenschaften).

Kennedy, Edward S. 1956a. “A Survey of Islamic Astronomical Tables”, *Transactions of the American Philosophical Society, New Series* **46-2**, pp. 123–177. Reprinted in 1989 with page numbering 1–55.

—— 1956b. “Parallax Theory in Islamic Astronomy”, *Isis* **47**, pp. 33–53. Reprinted in Kennedy *et al.* 1983, pp. 164–184.

—— 1977. “The Astronomical Tables of Ibn al-Aᶜlam”, *Journal for the History of Arabic Science* **1**, pp. 13–23.

Kennedy *et al.* 1983. *Studies in the Islamic Exact Sciences by E.S. Kennedy, Colleagues and Former Students* (David A. King & Mary Helen Kennedy, eds.), Beirut (American University in Beirut).

Kennedy, Edward S. & Agha, Muhammad 1960. “Planetary Visibility Tables in Islamic Astronomy”, *Centaurus* **7**, pp. 134–140. Reprinted in Kennedy *et al.* 1983, pp. 144–150.

Kennedy, Edward S. & Faris, Nazim 1970. “The Solar Eclipse Technique of Yaḥyā b. Abī Manṣūr”, *Journal for the History of Astronomy* **1**, pp. 20–38. Reprinted in Kennedy *et al.* 1983, pp. 185–203.

Kennedy, Edward S. & Kennedy, Mary Helen 1987. *Geographical Coordinates of Localities from Islamic Sources*, Frankfurt am Main (Institut für Geschichte der Arabisch-Islamischen Wissenschaften).

King, David A. 1986. *Islamic Mathematical Astronomy*, London (Variorum). Second edition with corrections: Aldershot (Variorum) 1993.

—— 1987. “Some Early Islamic Tables for Determining Lunar Crescent Visibility”, in: King & Saliba 1987, pp. 185–225. Reprinted in King 1993, II.

—— 1993. *Astronomy in the Service of Islam*, Aldershot (Variorum).

—— 2000. “Too Many Cooks ... A New Account of the Earliest Muslim Geodetic Measurements”, *Suhayl* **1**, pp. 207–241.

—— 2004. *In Synchrony with the Heavens. Studies in Astronomical Timekeeping and Instrumentation in Medieval Islamic Civilization. Volume One. The Call of the Muezzin (Studies I–IX)*, Leiden (Brill).

King, David A. & Saliba, George (eds.) 1987. *From Deferent to Equant: A Volume of Studies in the History of Science in the Ancient and Medieval Near East in Honor of E.S. Kennedy*, New York (The New York Academy of Sciences).

King, David A. & Samsó, Julio 2001. “Astronomical Handbooks and Tables from the Islamic World (750–1900): an Interim Report” (with a contribution by Bernard J. Goldstein), *Suhayl* **2**, pp. 9–105.

Kunitzsch, Paul 1964. “Das Fixsternverzeichnis in der „Persischen Syntaxis“ des Georgios Chrysokokkes”, *Byzantinische Zeitschrift* **57**, pp. 382–411. Reprinted in Paul Kunitzsch, *The Arabs and the Stars*, Northampton (Variorum) 1989, II.

Mercier, Raymond P. 1989. “The Parameters of the Zīj of Ibn al-A‘lam”, *Archives Internationales d’Histoire des Sciences* **39**, pp. 22–50.

von Mžik, Hans 1926. *Das Kitāb Ṣūrat al-Arḍ des Abū Ǧaᶜfar Muḥammad ibn Mūsā al-Ḫuwārizmī*, Leipzig (Harrassowitz).

Nallino, Carlo Alfonso 1899–1907. *al-Battānī sive Albatenii. Opus astronomicum*, 3 vols., Milan (Hoepli). Reprinted: Frankfurt am Main (Institut für Geschichte der Arabisch-Islamischen Wissenschaften) 1997.

Neugebauer, Otto 1962. *The Astronomical Tables of al-Khwārizmī*, Copenhagen (Det Kongelige Danske Videnskabernes Selskab / Munksgaard).

—— 1975. *A History of Ancient Mathematical Astronomy*, 3 vols., Berlin (Springer).

Rosenfeld, Boris A. & İhsanoğlu, Ekmeleddin 2003. *Mathematicians, Astronomers, and Other Scholars of Islamic Civilization and Their Works (7th–19th c.)*, Istanbul (IRCICA).

Sachau, C. Edward 1879. *The Chronology of Ancient Nations*, London (Oriental Translation Fund of Great Britain and Ireland / Allen). Reprinted: Frankfurt am Main (Institut für Geschichte der Arabisch-Islamischen Wissenschaften) 1998.

Saliba, George 1970. "Easter Computation in Medieval Astronomical Handbooks", *Al-Abhath* **23**, pp. 179–212. Reprinted in Kennedy *et al.* 1983, pp. 677–709.

Sezgin, Fuat 1978. *Geschichte des arabischen Schrifttums. Band VI: Astronomie bis ca. 430 H.*, Leiden (Brill).

—— 1979. *Geschichte des arabischen Schrifttums. Band VII: Astrologie – Meteorologie und Verwandtes bis ca. 430 H.*, Leiden (Brill).

—— (ed.) 1986. *The Verified Astronomical Tables for the Caliph al-Maʾmūn. Al-Zīj al-Maʾmūnī al-mumtaḥan by Yaḥyā ibn Abī Manṣūr. Reproduced from MS árabe 927, Escorial Library* (with an introduction by E. S. Kennedy), Frankfurt am Main (Institut für Geschichte der Arabisch-Islamischen Wissenschaften).

—— 2000. *Geschichte des arabischen Schrifttums. Band X–XII: Mathematische Geographie und Kartographie im Islam und ihr Fortleben im Abendland*, Frankfurt am Main (Institut für Geschichte der Arabisch-Islamischen Wissenschaften). An English translation is in preparation.

Suter, Heinrich 1914. *Die astronomischen Tafeln des Muḥammed ibn Mūsā al-Khwārizmī in der Bearbeitung des Maslama ibn Aḥmed al-Madjrīṭī und der latein. Uebersetzung des Athelhard von Bath*, Copenhagen (Det Kongelige Danske Videnskabernes Selskab / Høst).

Tihon, Anne 1989. "Sur l'identité de l'astronome Alim", *Archives Internationales d'Histoire des Sciences* **39**, pp. 3–21.

Van Brummelen, Glen R. 1998. "Mathematical Methods in the Tables of Planetary Motion in Kūshyār ibn Labbān's *Jāmiʿ Zīj*", *Historia Mathematica* **25**, pp. 265–280.

Vernet, Juan 1954. "Un antiguo tratado sobre el calendario judio en las «Tabulae Probatae»", *Sefarad* **14**, pp. 59–78. Reprinted in Vernet 1979, pp. 213–232.

—— 1956. "Las «Tabulae probatae»", in: *Homenaje a Millás-Vallicrosa*, Barcelona (Consejo Superior de Investigaciones Científicas), vol. II, pp. 501–522. Reprinted in Vernet 1979, pp. 191–212.

—— 1979. *Estudios sobre historia de la ciencia medieval*, Barcelona (Bellaterra).

Viladrich, Mercè 1988. "The Planetary Latitude Tables in the *Mumtaḥan Zīj*", *Journal for the History of Astronomy* **19**, pp. 257–268.

—— 1996. “The *Mumtaḥan* tradition in al-Andalus. Analysis of data from the *Calendar of Cordova* related to the entrance of the sun in the zodiacal signs”, in: *From Baghdad to Barcelona. Studies in the Islamic Exact Sciences in Honour of Prof. Juan Vernet* (Josep Casulleras & Julio Samsó, eds.), Barcelona (Instituto “Millás Vallicrosa” de Historia de la Ciencia Arabe), vol. 1, pp. 253–265.

Vollers, Karl 1906. *Katalog der islamischen, christlich-orientalischen, jüdischen und samaritanischen Handschriften der Universitäts-Bibliothek zu Leipzig* (mit einem Beitrag von Johannes Leipoldt), Leipzig (Harrassowitz). Reprinted: Osnabrück (Biblio Verlag) 1975.

Appendix: Complete table of contents of MS Leipzig, Universitätsbibliothek, Vollers 821

The following table of contents covers the text as well as the tables in the Leipzig manuscript. For each chapter, the folio number and line at which it starts is indicated. For each smaller table, the position on the folio is indicated by one of the abbreviations t (top), m (middle), b (bottom), l (left) and r (right). For tables longer than a single page the range of folios is given. My own additions to the titles are given between square brackets. To make clear which entries are texts and which are tables, I have inserted *[Fī]* before titles of chapters that start with “*Jadwal*” and *[Jadwal]* before titles of tables that do not start with “*Jadwal*”. Tables whose function is described in English do not have a heading. A longer horizontal line between two folios denotes a break in the manuscript. A shorter horizontal line preceded by a question mark indicates a situation where the previous page ends with a section or table and the following page starts with a new one, but the topics are so different that a break seems possible. Parts in between any two consecutive lines occur in the manuscript in the correct order. After each entry, a capital letter between parentheses refers to the paragraph of Section 2 in which the topic is discussed.

1^{r}: Second half of the table of numbers of days between epochs (continued from fol. 151^{v}, A).

1^{v}–2^{v}: *Jadwal al-tawārīkh al-muṣaḥḥaḥ li-istikhrāj baʿḍihā min baʿḍ wa-hiya al-majmūʿa / Jadwal al-sinīn al-mabsūṭa li-l-tawārīkh* (continued on fol. 34^{r}, A).

3^{r}:1 Continuation of a text on the determination of the seasonal hours and equal hours that have passed of the night (but not that on fol. 4^{v}, C).

3^{r}:14 *Maʿrifat maṭraḥ shuʿāʿāt al-kawākib* (according to the method of Drīnūsh, presumably Dorotheus; K).

3^{v}:1 *Fī maʿrifat ruʾūs al-ahilla bi-l-jadwal* (A).

3^{v}:b *Jadwal maʿrifat ruʾūs al-ahilla al-ʿarabiyya* (A).

4^{r}: Last quarter of the oblique ascension table for latitude 37°30′ (continued from fols. 108^{v}–109^{v}, C).

4^{v}:1 *Maʿrifat al-ẓill min qibal al-irtifāʿ bi-l-jadwal* (B, C).

4^{v}:15 *Maᶜrifat mā maḍā min al-layl min sāᶜa bi-qiyās al-kawākib al-thābita* (continuation missing from the manuscript, C).

5^{r}:1 Last words of an unidentified section: *wa-kawākibihi wa-l-salām*.

5^{r}:1 *Maᶜrifat taḥāwīl sini ʼl-ᶜālam* (K).

5^{v}:8 *Maᶜrifat taḥwīl sini ʼl-ᶜālam wa-l-mawālīd bi-l-jadwal* (K).

6^{v}:11 *Maᶜrifat al-samt min qibal al-irtifāᶜ wa-l-ṭāliᶜ* (K).

7^{r}:6 *Fī maᶜrifat ṭāliᶜ al-ᶜālam* (K).

7^{r}:10 *Fī maᶜrifat taḥwīl sana al-ᶜālam* (K).

7^{v}–8^{r}: *Jadwal taḥwīl sini ʼl-ᶜālam wa-l-mawālīd li-tisᶜīn sana ᶜalā mā raṣadahu al-sharīf Ibn al-Aᶜlam raḥimahu Allāh* (K).

8^{v}:1 *Fī maᶜrifat al-dāʾir min al-falak* (C).

?

9^{r}:1 *Maᶜrifat istikhrāj ṣawm al-naṣārā wa-mā yataᶜallaqu bi-hi* (A).

10^{r}: Table for Christian feasts and fasts to be entered with the remainders of the divisions of the Byzantine year minus 1204 by 28 and 19 (A).

10^{v}–12^{v}: Table for Christian feasts and fasts to be entered with a number from 1 to 70 found from the previous table (continued on fol. 29^{r}, A).

13^{r}: Continuation from fol. 30^{v} of a text concerning the calculation of lunar eclipses (H).

15^{v}:4–20^{v} *Fī maᶜrifat kusūf al-shams* (text: *al-qamar*) *wa-taᶜdīl azmānihi wa-ṭāliᶜ kull zaman minhā* (continuation missing from the manuscript, H).

21^{r}: Continuation from fol. 112^{v} of a text on the correction of the ascendant (K).

21^{v}:8 *Maᶜrifat ṭāliᶜ al-qubba* (K).

21^{v}:1 *[Jadwal] awj al-mirrīkh* (D).

22^{r}: *[Jadwal] ḥarakāt al-kawākib fi ʼl-awjāt ᶜalā raʾy Ibn al-Aᶜlam wa-huwa li-kull 70 sana daraja* (D).

22^{v}: *[Jadwal] ḥarakāt awjāt al-kawākib fi ʼl-sinīn wa-l-shuhūr wa-l-ayyām bi-l-miḥna wa-l-raṣad wa-huwa fī kull 66 sana daraja wāḥid ᶜalā raʾy al-Battānī wa-l-Maʾmūn wa-hādhihi ḥarakāt al-kawākib al-thābita ᶜalā mā wujidu* (D).

23^{r}:1 *Basmala*, followed by a text on a simplified method for calculating oblique ascensions, with two small tables (C).

23^{v}: Table of numbers of days of progressions, retrogressions and stations of the five planets (F).

24^{r}:1 *[Fī] jadwal taḥāwīl al-sinīn li-l-Maʾmūn li-l-dahr* (K).

24^{r}:12 *Maᶜrifat taḥwīl sanat al-ᶜālam* (K).

24^{v}–25^{r}: *Jadwal taḥāwīl al-sinīn li-l-dahr li-l-Maʾmūn* (K).

25^{v}–26^{v}: *Jadwal maṭāliᶜ al-burūj fi ʼl-falak al-mustaqīm* (C).

27^{r}: *Jadwal fuḍūl al-maṭāliᶜ li-ᶜarḍ kullihā* (C).

27^{v}:1 *Maᶜrifat al-ijtimāᶜ wa-l-istiqbāl li-l-shams wa-l-qamar* (H).

28^{v}: Universal table of oblique ascensions, only latitudes 1 to 33° (C).

29^{r}: Last page of the table of Christian feasts and fasts (continued from fols. 10^{v}–12^{v}, A).

29^{v}:1–30^{v} *Maʿrifat kusūf al-qamar wa-taʿdīl azmānihi wa-taʿdīl kull zaman minhu* (continued on fol. 13^{r}, H).

31^{r}: *[Jadwal] al-ẓill* (B).

31^{v}: *[Jadwal] mawāḍiʿ al-kawākib al-thābita min falak al-burūj wa-mamarrihā bi-dāʾirat niṣf al-nahār wa-aḥwālihā li-sanat 380 li-taʾrīkh Yazdigird* (continued on fol. 153^{r}, I).

32^{r}: *Jadwal ikhtilāf ʿarḍ al-qamar li-l-ruʾya* (H).

32^{v}–33^{r}: Lunar eclipse tables for nearest and furthest distance (H).

33^{v}: *Jadwal taʿdīl al-kusūfayn* (H).

34^{r}: *Jadwal tamām al-sinīn al-mabsūṭa li-l-tawārīkh* (continued from fol. 2^{v}, A).

34^{v}: *Fī dhikr aḥwāl al-burūj wa-l-kawākib* (continued on fol. 45^{r}, L).

35^{r}:1 Continuation from fol. 50^{v} of a standard text on planetary stations (F).

35^{r}:12 *Maʿrifat ʿarḍ al-qamar* (E).

35^{v}:2 *Fī maʿrifat taqwīm al-jawzahar* (E).

35^{v}:5 *Maʿrifat ẓuhūr al-kawākib wa-ikhtifāʾihā* (continuation missing from the manuscript, G).

36^{r}:1 Continuation from fol. 110^{v} of a text on lunar crescent visibility (G).

36^{r}:10 *Maʿrifat kusūf al-qamar bi-l-manāzil* (H).

36^{v}:11 *Maʿrifat alwān al-kusūf* (H).

37^{r}: *Jadwal istikhrāj al-manāzil li-kusūf al-qamar* (H).

37^{v}–40^{r}: *[Jadwal] al-manzila al-ūla li-kusūf al-qamar*, up to *al-manzila al-sādisa* (H).

40^{v}:1 *Fī maʿrifat kusūf al-shams* (H).

41^{v}–42^{r}: *Jadwal al-samt li-ʿilm kusūf al-shams* (H).

42^{v}: *Jadwal ʿarḍ al-shams* (H).

43^{r}: *Jadwal yuʿrafu minhu kusūf al-shams ṣaḥīḥ mujarrab idhā uḥsina al-ʿamal bihi* (H).

43^{v}:1 *Maʿrifat kusūf al-qamar bi-l-jadwal muqarrab* (H).

43^{v}:13 *Maʿrifat sini 'l-Iskandar [min sini 'l-hijra]* (A).

44^{r}: Table: *Fī maʿrifat al-kusūf bi-hādha 'l-jadwal* (H).

44^{v}:1 *Maʿrifat taḥāwīl al-sinīn bi-ziyādāt al-adwār* (K).

44^{v}:10 *Maʿrifat nuzūl al-shams ruʾūs* (text: *ruʾūs al-shams*) *al-burūj wa-masīrihā fī kull burj* (K).

44^{v}:15 *Maʿrifat maṭlaʿ al-shiʿrā* (continued on fol. 112^{r}, I).

45^{r}: Continuation from fol. 34^{v} of an introduction to astronomy (L).

47^{v}:5 *Fī maʿrifat istikhrāj awsāṭ al-kawākib* (D).

49^{r}:4 *Fī maʿrifat taqwīm al-shams* (D).

49^{r}:12 *Fī maʿrifat taqwīm al-qamar* (D).

49^{v}:15 *Bāb fī maʿrifat taqwīm zuḥal [wa-mushtarī wa-mirrīkh]* (D).

50^{v}:9 *wa-ammā taqwīm al-zuhara wa-l-ʿuṭārid ...* (D).
50^{v}:12 *Maʿrifat rujūʿ al-kawākib wa-istiqāmatihā* (continued on fol. 35^{r}, F).

51^{r}: Continuation of a text on the calculation of planetary visibility (G).
51^{v}–52^{r}: *Jadwal ruʾyat al-kawākib al-khamsa wa-ikhtifāʾihā* (G).
52^{v}:1 *Fī maʿrifat al-jayb* (B).
53^{v}:3 *Fī maʿrifat ʿamal al-juyūb wa-l-qisī bi-l-jadwal* (B).
53^{v}:18 *Fī maʿrifat taqwīs al-jayb* (B).
54^{r}:8 *Maʿrifat ʿamal al-jayb al-maʿkūs* (B).
54^{r}:16 *Fī maʿrifat taqwīs al-jayb maʿkūsan* (B).
54^{v}:5 *Maʿrifat al-mayl al-aʿẓam wa-ʿilm ḥisābihi* (C).
55^{r}:11 *Maʿrifat ḥisāb al-mayl li-ajzāʾ falak al-burūj* (C).
55^{v}:4 *Maʿrifat ḥisāb ʿarḍ al-qamar* (E).
55^{v}:13 *Maʿrifat mayl al-shams bi-l-jadwal wa-huwa buʿduhā ʿan dāʾirat muʿaddil al-nahār* (C).
56^{r}:13–56^{v} *Fī maʿrifat ʿarḍ al-qamar bi-l-jadwal* (E).

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57^{r}: *Fī maʿrifat kusūf al-qamar bi-l-jadwal li-Yaḥyā ibn Abī Manṣūr ṣaḥīḥ*, with three small tables (H).
57^{v}–60^{r}: *Jadwal maqāmāt al-kawākib* (F).
60^{v}:1 *Fī maʿrifat ʿurūḍ al-kawākib ʿalā madhhab Baṭlamiyūs muqarrab* (E).
60^{v}:6 *Fī maʿrifat jawzahar al-kawākib* (E).
60^{v}:11 *Maʿrifat mawāḍiʿ jawzaharāt al-kawākib* (E).
60^{v}:15 *Awjāt al-kawākib* (D).
61^{r}:6 List of mean motion parameters for Mars by Ibn al-Aʿlam (D).
61^{v}–63^{v}: *Jadwal ʿarḍ zuḥal / mushtarī / mirrīkh / zuhara / ʿuṭārid* (E).
64^{r}:1 *Fī maʿrifat al-mayl wa-ʿarḍ al-qamar* (C, E).
64^{v}–65^{v}: *[Jadwal] al-mayl [wa-]ʿarḍ al-qamar* (C, E).

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66^{r}–66^{v}: *[Jadwal] wasaṭ al-shams fi 'l-sinīn al-majmūʿa wa-l-mabsūṭa wa-l-shuhūr / wasaṭ al-shams fi 'l-ayyām wa-l-sāʿāt wa-l-kusūr* (D).
67^{r}–68^{r}: *Jadwal taʿdīl al-shams al-awj 82 39* (D).
68^{v}–69^{r}: *Jadwal masīr wasaṭ al-qamar* (double elongation, D).
69^{v}–70^{r}: *Jadwal masīr tadwīr al-qamar* (mean longitude, D).
70^{v}–71^{r}: *Jadwal masīr khāṣṣat al-qamar* (mean anomaly, D).
71^{v}–72^{r}: *Jadwal wasaṭ al-jawzahar* (D).
72^{v}–75^{r}: *Jadāwil taʿdīl al-qamar* (D, E).
75^{v}–76^{r}: *Jadwal masīr wasaṭ zuḥal* (D).
76^{v}–77^{r}: *Jadwal masīr khāṣṣat zuḥal* (D).
77^{v}–80^{r}: *Jadāwil taʿādīl zuḥal al-awj 8 4 30* (D, F).
80^{v}–81^{r}: *Jadwal masīr wasaṭ al-mushtarī* (D).
81^{v}–82^{r}: *Jadwal masīr khāṣṣat al-mushtarī* (D).
82^{v}–85^{r}: *Jadāwil taʿādīl al-mushtarī awjuhu 172 32* (D, F).
85^{v}–86^{r}: *[Jadwal] wasaṭ al-mirrīkh* (D).

86^{v}–87^{r}: *[Jadwal] wasaṭ masīr al-mirrīkh* (corrected in the same hand to: *Jadwal masīr khāṣṣat al-mirrīkh)* (D).
87^{v}–90^{r}: *Jadāwil taᶜādil al-mirrīkh wa-hādha ’l-mirrīkh huwa mirrīkh Ibn al-Aᶜlam wa-huwa ajwaduhā 128 50* (D, F).
90^{v}–91^{r}: *Jadwal masīr khāṣṣat al-zuhara* (D).
91^{v}–94^{r}: *Jadāwil taᶜādil al-zuhara al-awj ...* (D, F).
94^{v}–95^{r}: *Jadwal masīr khāṣṣat al-ᶜuṭārid* (D).
95^{v}–98^{r}: *Jadāwil taᶜādil ᶜuṭārid al-awj 1 0 2 0 (?) / 244 30* (D, F).
98^{v}:1 *Fī maᶜrifat al-jayb bi-l-jadwal* (B).
99^{v}: *Jadwal al-jayb wa-l-qaws* (B).

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100^{r}:1 *Maᶜrifat niṣf qaws al-nahār wa-ajzāʾ sāᶜāt al-nahār wa-l-layl* (continued from fol. 130^{v} with one folio missing, C).
100^{r}:11 *Maᶜrifat sāᶜāt al-nahār al-mustawiya* (C).
100^{r}:16 *Maᶜrifat ajzāʾ sāᶜāt al-nahār* (C).
100^{v}:3 *Maᶜrifat taḥwīl al-sāᶜāt al-mustawiya ila ’l-muᶜwajja* (C).
100^{v}:10 *Fī maᶜrifat jayb al-nahār wa-l-layl* (C).
100^{v}:18 *Fī maᶜrifat kam maḍā min al-nahār min sāᶜat bi-qiyās al-shams wa-l-ᶜamal bihi* (C).
101^{r}:10 *Fī maᶜrifat irtifāᶜ niṣf al-nahār* (C).
101^{r}:15 *Maᶜrifat taḥwīl daraj al-sawā ilā daraj al-maṭāliᶜ* (and vice versa, C).
101^{v}:5 *Maᶜrifat saᶜat al-mashāriq*, *wa-nabdaʾu bi-l-shams* (C).
101^{v}:15 *Maᶜrifat saᶜat al-mashāriq* (C).
102^{r}:5 *Fī maᶜrifat iqāmat al-ṭāliᶜ wa-l-buyūt al-ithnā ᶜashara* (C).
103^{r}–104^{r}: *Jadwal maṭāliᶜ al-falak al-mustaqīm* (C).
104^{v}–106^{r}: *Jadwal maṭāliᶜ al-burūj li-ᶜarḍ Baghdād wa-ḥayth al-ᶜarḍ 33 0* (C).
106^{v}–108^{r}: *Jadwal maṭāliᶜ al-burūj li-ᶜarḍ al-Raqqa wa-ḥayth al-ᶜarḍ 36* (C).
108^{v}–109^{v}: *Jadwal maṭāliᶜ al-burūj li-ᶜarḍ Mayyāfāriqīn wa-Āmid wa-Arzan wa-Badlīs wa-Khilāṭ wa-ḥayth al-ᶜarḍ 37 30* (continued on fol. 4^{r}, C).

110^{r}:1 *Maᶜrifat masīr al-nayyirayn li-sāᶜa mustawiya* (H).
110^{r}:7 *Maᶜrifat ruʾyat al-hilāl* (G).
110^{v}:15 *Wajh ākhar fi ’l-ruʾya* (continued on fol. 36^{r}, G).

111^{r}: *Jadwal ikhtilāf al-manẓar* (H).
111^{v}: *Jadwal taᶜdīl al-kusūfāt al-shamsiyya* (H).

112^{r}:1 Continuation from fol. 44^{v} of a text on the heliacal rising of Sirius (I).
112^{r}:8 *Maᶜrifat sinī Yazdigird al-fārisī [min sini ’l-Iskandar]* (A).
112^{r}:18 *Maᶜrifat ruʾyat al-ahilla* (G).
112^{v}:7 *Bāb al-namūdhārāt* (continued on fol. 21^{r}, K).

113^{r}:1 Continuation of a text on the determination of the weekday of the beginning of a month (in an undetermined calendar, A).
113^{r}:3 *Fī maᶜrifat al-aṣl al-rūmī* (A).

113^{v}:5 *Maʿrifat ʿalāmat sanat al-rūm wa-madākhil shuhūrihim fi ʾl-ayyām al-sabʿa* (A).

114^{r}:3 *Fī istikhrāj al-tawārīkh baʿḍihā min baʿḍ* (deals in fact with the beginnings of the Arabic months, A).

114^{r}:17 *Maʿrifat istikrāj al-ʿarabī min al-fārisī* (A).

114^{v}:6 *Fī maʿrifat taʾrīkh Dhi ʾl-qarnayn min taʾrīkh al-furs* (A).

114^{v}:15 *Maʿrifat taʾrīkh al-furs min taʾrīkh Dhi ʾl-qarnayn* (A).

115^{r}:6 *Fī maʿrifat istikhrāj al-yūnānī min al-ʿarabī* (A).

115^{v}:1 *Fī maʿrifat istikhrāj sini ʾl-furs min al-ʿarabī* (A).

115^{v}:10 *Fī maʿrifat istikhrāj al-qibṭī min al-ʿarabī* (A).

116^{r}:3 *Fī maʿrifat istikhrāj al-ʿarabī min al-yūnānī* (A).

116^{r}:15 *Fī maʿrifat ruʾūs shuhūr al-furs* (A).

116^{v}:8 *Fī maʿrifat sini ʾl-rūm wa-ruʾūs shūhūrihim* (A).

117^{r}:1 *Fī maʿrifat raʾs sanat al-qibṭ wa-shuhūrihim* (A).

117^{r}:9 *Fī maʿrifat ruʾūs al-shuhūr al-ʿarabiyya ʿalā raʾy al-Battānī* (A).

121^{v}:10 *Fī maʿrifat al-sana al-kabīsa* (in the Byzantine calendar, A).

121^{v}:14 *Fī maʿrifat dukhūl shuhūr al-ahilla bi-l-jadwal* (A).

122^{r}:4 *Fī maʿrifat shuhūr al-yūnāniyyīn wa-l-sana al-kabīsa bi-l-jadwal* (A).

122^{r}:11 *Maʿrifat shuhūr al-furs wa-raʾs sinīhim bi-l-jadwal* (A).

122^{v}: *al-Jadwal al-mujarrad li-l-Hijra* (A).

123^{r}: *al-Jadwal al-mujarrad li-Dhi ʾl-qarnayn al-Iskandar* (A).

123^{v}:t *al-Jadwal al-mujarrad li-istikhrāj raʾs sanat al-furs* (A).

123^{v}:1 *Fī maʿrifat taʿdīl daqāʾiq al-ḥiṣṣa* (L).

123^{v}:8 *Fī maʿrifat al-kawkab rājiʿ huwa aw mustaqīm* (F).

124^{r}:16 *Fī maʿrifat ḥiṣaṣ al-kawkab li-yawm* (D).

124^{r}:18 *Maʿrifat masīr khāṣṣat al-kawkab li-yawm* (D).

124^{v}:5 *Wajh muqarrab malīḥ fī taʿdīl al-ayyām* (D).

124^{v}:10 *wa-hādha ʾlladhī yaʾtī min al-Battānī ...* (on the heavenly sphere, divisions of the ecliptic, multiplication and division; L).

128^{r}:9 *Fī maʿrifat sāʿāt al-taqwīm fī kull balad dhi ʾl-sāʿāt al-muʿtadila al-wusṭā* (L).

129^{v}:12 *Fī maʿrifat ʿarḍ al-qamar wa-jihatihi* (continued on fol. 131^{r}, E).

130^{r}:1 Continuation of a text on the hours of day and night (only the title is missing, which is given as *Maʿrifat al-sāʿāt al-muʿwajja wa-tusammā ajzāʾ al-sāʿāt* in **E**, p. 162, line 3; C).

130^{r}:9 *Wajh ākhar fī ʿilm azmān al-sāʿāt* (C).

130^{r}:13 *Maʿrifat sāʿāt al-layl* (C).

130^{v}:5 *Fī maʿrifat maṭāliʿ al-burūj fi ʾl-buldān* (one folio missing, then continued on fol. 101^{r}, C).

131^{r}:1 Continuation from fol. 129^{v} of a text on lunar latitude (E).

131^{r}:12 *Fī ṭulūʿ al-khamsa al-mutaḥayyira wa-ghurūbihā* (G).

133^{r}:8 *Fī maʿrifat miqdār mayl falak al-burūj ʿan falak muʿaddil al-nahār* (C).

133^{v}:14 *Maʿrifat maṭāliʿ al-burūj fi ʾl-falak al-mustaqīm* (C).
134^{v}:4 *Fī maʿrifat irtifāʿ al-quṭb min qibal ziyādat al-nahār al-aṭwal* (C).
135^{r}:1 *Fī maʿrifat ziyāda al-nahār al-aṭwal wa-mā dūnahu min ziyādāt al-nahār* (C).
135^{v}:3 *Fī maʿrifat al-irtifāʿ wa-l-ẓill aḥadihimā min qibal al-ākhar bi-l-ḥisāb wa-l-jadwal* (B, C).
135^{v}:18 *Fī maʿrifat samt al-irtifāʿ wa-l-ẓill min dāʾirat al-ufq fī kull balad wa-fī kull waqt* (C).
136^{v}:6 *Fī maʿrifat khaṭṭ niṣf al-nahār fī kull balad* (C).
137^{v}:17 *Fī maʿrifat maṭāliʿ al-burūj fī kull balad* (C).
139^{r}:5 *Taṣnīf al-ʿamal bi-l-maṭāliʿ* (C).
141^{r}:3 *Fī maʿrifat ʿurūḍ al-buldān* (C).
141^{r}:13 *Fī maʿrifat irtifāʿ al-shams fī waqt aṣnāf al-nahār min kull yawm* (C).
141^{v}:10 *Fī taḥqīq aqdār al-ittiṣālāt* (K).
144^{r}:9 *Fī ṣifat al-rukhāma li-maʿrifat al-sāʿāt al-zamāniyya al-māḍiya min al-nahār bi-l-shams fī kull balad turīd* (L).
147^{r}:4 *Fī maʿrifat ʿamal al-tawārīkh baʿḍihā min baʿḍ min qibal al-jadwal* (A).
147^{v}:4 *Tafṣīl al-tawārīkh min qibal al-jadwal* (A).
147^{v}:17 *Maʿrifat taʾrīkh al-rūm wa-Diqliṭiyānūs min qibal al-jadwal* (A).
149^{r}:1 *Fī maʿrifat taʾrīkh Diqliṭiyānūs bi-l-jadwal* (A).
149^{r}:7 *Maʿrifat taʾrīkh al-hijra min qibal al-jadwal* (A).
149^{v}:17 *Maʿrifat al-tawārīkh baʿḍihā min baʿḍ bi-l-jadwal* (A).
150^{v}:1 *Maʿrifat taʾrīkh al-ṭūfān min taʾrīkh Dhi ʾl-qarnāyn* (A).
151^{v}: Table without title: number of days between epochs (continued on fol. 1^{r}, A).

152^{r}: Last page of the geographical table (continued from fol. 155^{v}, J).
152^{v}:1 *Fī maʿrifat mawḍiʿ al-raʾs wa-l-dhanab* (E).
152^{v}:6 *Fī dhikr kusūf al-qamar bi-dāʾirat al-kusūf* (continuation missing from the manuscript, H).

153^{r}: Second page of the star table for 380 Yazdigird (continued from fol. 31^{v}, I).
153^{v}–155^{v}: *Awsāṭ al-buldān wa-ismāʾihā / Aṭwāl al-buldān wa-ʿurūḍihā ʿalā mā fī Kitāb Ṣūrat al-arḍ* (continued on fol. 152^{r}, J).

156^{r}-157^{v}: Text and tables on chronology in a different hand.