Ibn Yunus, Abu?L-Hasan ?Ali Ibn ? Abd Al-Rahman Ibn Yunus Al Sadafi | Encyclopedia.com

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(d. Fustāt, Egypt, 1009)

astronomy, mathematics.

Ibn Yūnus was one of the greatest astronomers of medieval Islam. He came from a resepected family, his great-grandfather Yūnus having been a companion of the famous legal scholar al-Shāfi'ī and his father, 'Abd al Rahmān, being a distinguised historian and scholar of *hadīth* (the sayings of Muhammad). Besides being famous as an astronomer and astrologer, Ibn Yūnus was widely been preserved. Unfortunately nothing of consequence is known about his early life or education.

We know that as a young man Ibn Yānus witnessed the Fatimid conquest of Egypt and the foundation of Cairo in 969. In the period from 977 to 996, which corresponds roughly to the reign of Caliph al-ʿAzīz,vations that were renewed by order of Caliph al-Hakim, who succeeded al-ʿAziz in 996 at the age of in 996 at the age of eleven and was much interested in astrology. Ibn Yūnus' recorded observations continued until 1003.

Ibn Yūnus' major work was *al-Zīj al-Hākimī al-kabīr, zij* meaning an astronomical handbook with tables. It is a particularly fine representative of a class of astronomical handbooks, numbering perhaps 200, compiled in medieval Islam. The *Zij* of Ibn Yūnus was dedicated to Caliph al-Hākim and was aptly named *al-kabīr* ("large"). The text of the first forty–four of the eighty–one chapters of the original work is twice the length of the text of the *Zij* by al-Battānī and contains more than twice as many tables as the earlier work. The only extant chapters of the *Hākimī zij* are in two unpublished manuscripts at Leiden and Oxford, comprising about three hundred folios. A manuscript in Paris contains an hundred folios. A manuscript in Paris contains an anonymous abridgment of part of the *Zij* and is a source for some additional chapters up to chapter 57, and chapters 77–81.

The importance of Ibn Yūnus was realized in the West when the Leiden manuscript was first seriously studied. In 1804, Armand–Pierre Caussin de Perceval published the text of Ibn Yūnus' observational reports with a French translation. He also included the introduction to the *Zīj* which contains the titles of the eighty–one chapters. J,–J. Sedillot's translation (now lost) of the Leiden and Paris manuscripts was summarized by Delambre in 1819. The German scholar Carl Schoy published several articles containing translations and analyses of individual chapters of the *Zīj* relating to spherical atronomy and sundial theory.

The *Hākimī zīj* deals with the standard topics of Islamic astronomy but is distinguished from all other extant zījes by beginning with a list of observations made by Ibn Yūnus and of observations made by some of his predecessors, quoted from their works. Despite the critical attitude of Ibn Yunus toward these earlier scholars and his careful recording of their observations and some of his his own planetary parameters–nor does he indicate whether he used any instruments for these observations. In deed. the Hākimī zīj is a poor source of information about the instruments used by Ibn Yunus. In his account of measurements of the latitude of Fustat and of the obliquity of the ecliptic from solar meridian altitudes at the solstices, Ibn Yūnus states that he used an instrument provided by Caliph al-ʿAzīz and Caliph al-Hākīm. Although he describes it only by mentioning that the divisions for each minute of are were clearly visibl;e onb its scale, the instrument was probably a large meridian ring. His only other references to instruments used for simple observationjs are to an astrolanbe and a gnomon.

In view of the paucity of this information, it is remarkable that the statement that Ibn Yūnus worked in a" well–equipped observatory" is often found in popular accounts of Islamic astronomy. A. Sayili, *The Observatory in Islam,* has shown how this notion gained acceptance in Western literature.

There are two sources, however, that might cast a little more light on the sitution if their reliability could be established. First, the historian Ibn Hāmmad (fl. ca. 1200) mentions a copper instrument, resembling an astrolabe three cubits in diameter, that a contemporary of his had seen and associated with the Hākimī observations, Likewise the Yemenite Sultan al-Ashraf (fl. ca. 1290), who was an astronomer, records that al-Hākim had an armillary sphere consisting of nine rings, each of which weighed 2,000 pounds and was large enough for a man to ride through on horseback. The possibility that this instrument was that known to have been constructed in Cairo about 1125–over a century after the death of Ibn Yunus–cannot yet be discounted.

There is evidence that al-Hākim had a house on the Muqattam hills overlooking Cairo, which may have contained astronomical instruments: Ibn Yunus is known to have visited this house on one occasion to make observations of Venus. Never theless, al-Hākim's unsuccessful attempt to build an observatory in Cairo took place after Ibn Yunus' death; and the only locations mentioned by Ibn Yūnus' in his own accounts of his observations are the Mosque of Ibn Nasr al-Maghribī at al-

Qarāfa, and the house of his great–grandfather Yūnus, in nearby Fustāt. A note written in the fifteenth century on the title folio of the Leiden manuscript of the *Hākimī zīj* states that Ibn Yūnus' observations were made in the area of Birkat al-Habash in Fustāt.

Ibn Yūnus explains in the introduction to his *Zīj* that the work is intended to replace the *Mumtahan zīj* of Yahyā ibn Abī Mansūr, prepared for the Abbasid Caliph al-Maʿmūn in Bagadad almost 200 years earlier. Ibn Yūnus reports the observations of some astronomers before his own time, in which what was observed was at variance with what was calculuated with the tables of the *Mumtahan zīj*. When reporting his own observations. Ibn Yūnus often compares what he observed with what he had computed with the *Mumtahan* tables.

From the introduction and chapter 4, 5, and 6 of the *Hākimī zīj,* which contain the observation accounts, it is clear that Ibn Yūnus was familiar with the *zījes* of habash al-Hāsib, al-Battānī, and al-Nayrīzī, as well as the *Mumtahan zīj* The observations made by al-Māhani, whose works are not extant. He lists the planetary parameters of the *Mumtahan zīj* and this has enabled the positive identification of at least the planetary tables in the only extant manuscript of this early work, which contains considerable spurious material. Ibn Yūnus also quotes observations made by the Banū Amajur family in Baghdad; their five *zījes* are not extant. Other works quoted by Ibn Yūnus, although not necessarily ddirectly, are the *zījes* of al-Nihāwandī; Ibn al-Adamī, the Banū Mūsā, Abī Ma'shar, Ibn al-A'lam, al-Sūfī, and Muhammad al-Samarqandī ;none of these works is extant, and Ibn Yūnus' references provide valuable information about them.

The observations described by Ibn Yūnus are of conjunctions of planets with each other and with Regulus, solar and lunar eclipses, and equinoxes; he also records measurements of the obliquity of the ecliptic (chapter 11) and of the maximum lunar latitude (chapter 38). All of these accounts are notable for their lack of information on observational procedures. The following passage is a translation of one of Ibn Yūnus' accounts of a planetary conjunction that he had observed:

A conjunction of Venus and Mercury in Gemini, observed in the western sky: The two planets were in conjunction after sunset on the night whose morning was Monday, the thirteenth day of Jumādā II 390 Hegira era. The time was approximately eight equinoctial hours after midday on Sunday, which was the fifth day of Khardādh, 369 Yazdigird era. Mercury was north of Venus and their latitude difference was a third of a degree. According to the *Mumtahan Zīj* their longitude difference was found and a half degrees [A. P. Caussin de Perceval," Le livre de la grande table Hakémite," in *Notices et extraits des manuscrits de la Bibliotheque nationale,***7** (1804), p.217].

The Sunday metioned was 19 May 1000,and computation with modern tables confirms that there was a conjunction in longitude that evening and the Mercury was indeed one-third degree north of Venus. About forty such planetary conjunctions observed by Ibn Yūnus are described in the *Zīj*.

The following passage is a translation of Ibn Yūnus' account of the lunar eclipse that occurred on 22 April 981 (Oppolzer no. 3379):

This lunar eclipse was in the month of Shawwāl, 370 Hegira era, on the night whose morning was Friday, the third day of Urdibihisht, 350 Yazdigard era. We gathered to observe this eclipse at al-Qarāfa, in the Mosuqe of Ibn Nasr al-Maghribī. we perceived first contact when the altitude of the moon was approximately 21^2. About a quarter of the lunar diameter was eclipsed, and reemergence occured about a quarter of an hour before sunrise [A. P. Caussin de Perceval, p.187].

Some of the thirty eclipses reported by Ibn Yūnus were used by Simon Newcomb in his determination of the secular acceleration of the moon. More recently, other observations recorded in the *Hākimī zīj* have been used by R. Newton.

The first chapter of the *Zīj* is the longest of the extant chapters and deals with the Muslim, Coptic, Syrian, and Persian calendars. There are detailed instructions for converting a date in one calendar to any of the other calendars, and extensive tables for that purpose. There are also tables for determining the dates of Lent and Easter in both the Syrian and the Coptic calendars. Such tables are found in several Islamic *zījes*

Chapters 7 and 9, on planetary longitudes, contain instructions for determining true longitudes from the tables of mean motion and equations. No theory is described, but the theory underlying the instructions and tables is entirely Ptolemaic. the mean motions differ from those used by Ibn Yūnu's predecessors, and his values for the sun and moon were deemed sufficiently reliable by al-Tūsī to be used in the *Īlkhānī zīj* 250 years later. Ibn Yūnnus' planetary tables are computed for both the Muslim and Persian calenders, and define the mean positions of the sun, moon, and planets, as well as the astrologically significant "comet" *alkayd,* for over 2,700 Muslim and 1,800 Persian years from the respective epochs 622 and 632.

For the year 1003, Ibn Yūnnus gives the solar apogee as Gemini $26;10^0$ and the maximum solar equation as $2;0,30^0$ Corresponding toa double eccentricity of $2;6,10^0$ (where the solar deferent radius is 60). No solar observations made by Ibn Yūnnus are recorded in the *Zīj* He changes the values of the lunar epicycli radius and the eccentricity from Ptolemy's $5;15^0$ also used in the *mumtahan zīj,* to $5;1,14^0$ and $11;7^0$ respectively (the latter is not used consistently), again wihtout expalnation. His planetary equation tables are idential with thosse of Ptolemy's *Handy Tables* and the *mumtahan zīj* for Saturn, jupiter, and Mars. For Venus, Ibn Yūnnus assumes an accentricity excatly half that of the sun and uses an epicyclic radius of 43;42 rather than Ptolemy's 43;10. For Mercury he adopts a maximum equation of $4;2^0$ an Indian parameter previously used in the *Zīj* of al-

Khwārizmī, rather than Ptolemy's 3;2^0 Ibn Yūnus' tables of equation for the moon, Venus, and Mercury contain the same inconsistencies as al–Bāttanī tables for Venus, in that some of the columns are not adjusted for the new parameters; this is a fairy common feature in Islamic *zījes* There is evidence that Ibn Yunus was not altogether satisfied with his determination of the planetary apogees: the *HāB;kimī zīj* contains three different sets of values (chapter 6,8 and 9)

In his discussion of solar and lunar distances 9chapters 55, 56), Ibn Yūnnus assumes a maximum solar parallax of 0;1,57^0 instead of Ptolemy's value of 0;2,51^0 Chapters 59–75, on parallax and eclipse theory and the associated tables, are not in the known manuscripts; and their recovery in other sources would be extremely valuable for the study of Islamic astronomy.

In chapter 38, on lunar and planetary latitudes, Ibn Yūnus states that he found the maximum lunar latitude to be 5;3°. Although he says that he measured it many times and repeatedly found this value, he does not say how the measurements were made. He did not pursue the suggestion of the Banu Amajur that he quotes: that the maximum lunar latitude was not constant. His planetary latitude tables are derived from those in the *Almagest*, except in the case of Venus, for which he used values originally taken from the *Hands Tables*.

Ibn Yūnus measured the position of Regulus as Leo 15;55°in 1003. His value for the motion of the fixed stars is 1° in 70 1/4 Persian years (of 365 days) and apparently was computed by using his own observation of Regulus and that made by Hipparchus; it is the most accurate of all known Islamic values. He had information at his disposal from which he might have deduced that the motion of the planetary apogees was different from the motion of the fixed stars, but he chose to conclude that the apogees moved at the same rate as the stars (chapter 8)

The trigonometric functions used by Ibn Yunus are functions of arcs rather than angles, and are computed for radius 60, as was standard in Islamic works. Chapter 10 of the *Zīj* contains a table of sines for each 0;10° of are, computer to four signicant sexagesimal digits. The values are seldom in error by more than ±2 in the fourth digit. Ibn Yunus determined the sine of 1 °to be 1; 2,49,43,28 (to base 60), using a method equivalent to interpolating linearly between the values of sin *x/x* for *x*=15/16°and 9/8°. He then improved this value by a rather dubious technique to obtain 1; 2,49,43,4. The accurate value to this degree of precision is 1,2,49,43,11. lbn Yūnus' younger contemporary al-BĪrūni was able to calculate the chord of a unit circle subtended by an angle of 1°correctly to five significant sexagesimal digits. Although in chapter 11 of the *Zīj* Ibn Yunus tabulates the cotangent function to three sexagesimal digits for each ten minutes of arc, he does not take full advantage of it. Many of the methods he suggests throughout the *Zīj* require divisions of sines by cosines: and he uses the cotangent function, which he calls the shadow, only when the argument is an altitude arc.

In spherical astronomy (chapters 12–54) Ibn Yunus reached a very high level of sophistication. Although none of his formulas is explained, it seems probable that most of them were derived by means of orthogonal projections and analemma constructions, rather than by the application of the rules of spherical trigonometry that were being developed by Muslim scholars in Iraq and Persia. Altogether, there are several hundred formulas outlined in the *Zīj*, many of which are trivially equivalent. These are stated in words and without recourse to any symbols. For each method outlined, Ibn Yunus generally gives at least one numerical example. The problems of spherical astronomy discussed in the *Hākimī zīj* are more varied than those in most major Islamic *zījes*, and the following examples are intended to illustrate the scope of the treatment.

Ibn Yūnus describes several methods for computing right and oblique ascensions (chapters 13, 14). He also computes both, the latter for each degree of the ecliptic and for each degree of terrestrial latitude from 1°to48° according to Mansūr ibn ʿIrāq, "there is no one who studies this sort of thing or even thinks about it"). Ibn Yunus discusses in great detail the determination of time and solar azimuth from solar altitude, and it will be clear from the tables mentioned below that he devoted much effort to these problems. Certain functions that he discusses in the text are also tabulated, such as the solar altitude in the prime vertical and the rising amplitude of the sun (that is, the distance of the rising sun from the east point). The problem of finding solar altitude from solar azimuth (chapter 24) is not so simple as of arc, computed to four signif the inverse problem; but Ibn Yunus solves it in several ways, including the use of an algebraic method. He also tabulates the solar altitude for certain azimuths, such as that of the qibla, the direction of Mecca (chapter 28), and ten different azimuths (chapter 24), to be used for finding the meridian. Several geometric solutions to the problem of determining the *qibla*, a favorite of the Islamic astronomers, are also outlined. One of Ibn Yunus' solutions is equivalent to successive applications of the cosine rule and sine rule for spherical triangles, but is derived by a projection method that was also used by the contemporary Egyptian scholar Ibn al-Haytham.

Particularly elegant solutions are presented for finding the meridian from three solar observations on the same day (chapter 23) and for finding the time between two solar observations on the same day (chapter 33). The latter problem is solved by a direct application of the cosine rule for plane triangles, the earliest attested use of this rule. Ibn Yunus transforms ecliptic to equatorial coordinates (chapter 39) by a method equivalent to the cosine rule for spherical triangles but probably derived by means of an analemma construction . His sundial theory (chapters 26, 27, 35) is also of considerable sophistication. It deals with horizontal and vertical sundials, the latter oriented in the meridian, the prime vertical, or a general direction inclined to both. He proves geometrically that for a horizontal sundial the gnomon shadow measures the altitude of the upper rim of the solar disk, and stresses the precautions to be taken when setting the gnomon on a marble slab to ensure that it is aligned correctly.

The chapters of the *Zīj* dealing with astrological calculations (77-81), although partially extant in the anonymous abridgment of the work, have never been studied. Ibn Yūnus was famous as an astrologer and, according to his biographers, devoted much time to making astrological predictions. His *Kitāb bulūgh al-uminiyya* ("On the Attainment of Desire") consists of twelve chapters devoted to the significance of the heliacal risings of Sirius when the moon is in any of the twelve zodiacal signs, and to predictions based on the day of the week on which the first day of the Coptic year falls.

In chapter 10 of the *Hākimī zīi* Ibn Yunus states that he had prepared a shorter version of his major work: this, unfortunately, is no longer extant. There are, however, numerous later *zījes* compiled in Egypt, Persia, and Yemen that are extant and contain material ultimately due to Ibn Yunus. For example. the thirteenth-century Egyptian Mustalall *zīj*, as well the īlkhāuā:zīj of al-Tūsi and the *Zīj* of Muhyi'l-Din al-Maghribi, both compiled at the observatory in Maragha, Persia, in the thirteenth century. relied on the *Hakimī: zīj*. Likewise, the Mukhtar: ijby the thirteenth-century Yemenite astronomer Abu'l-'Uqul is based mainly on a *zīj* by Ibn Yunus other than the *Hākimī*; and an anonymous fourteenth-century Yemenite,. *zīj* is adapted from the *Hānkimi zīj*

There are other sets of tables preserved in the manuscript sources and attributed to Ibn Yūnus that are distinct from those in the *Hākimī zīj* but based on them. First, Ibn Yūnus appears to be the author of tables of the sine and tangent functions for each minute of arc, as well as tables of solar declination for each minute of solar longitude. These sine tables display values of the sine function to five sexagesimal digits, which is roughly equivalent to nine decimal digits. The values are often in error in the fourth sexagesimal digit, however, so that it was a premature undertaking. Indeed, over four centuries passed before the compilation of the trigonometric tables in the *Zīj* of Ulugh Beg in Samarkand, in which values are also given to five sexagesimal digits for each minute of arcbut are generally correct. Second, it appears that Ibn Yūnus was the author of an extensive set of tables, called *al-Ta'dīl al-muhkam*, that display the equations of the sun and moon; the latter are of particular interest. They are based on those in the *Hākimi zīj* but are arranged so as to facilitate computation of the lunar position: the equation is tabulated as a function of the double elongation and mean anomaly, both of which can be taken from the mean motion tables; thus there is no need to find the true anomaly. The table, which accurately defines the Ptolemaic lunar equation for Ibn Yunus' parameters, contains over 34,000 entries.

Ibn Yūnus' second major work was part of the corpus of spherical astronomical tables for timekeeping used in Cairo until the nineteenth century. It is difficult to ascertain precisely how many tables in this corpus, which later became known as the *Kitāb ghayat al-intifa*' ("Very Useful Tables"), were actually computed by Ibn Yunus. Some appear to have been compiled by the late thir-teenth-century astronomer al-Maqsī. The corpus exists in numerous manuscript sources, each containing different arrangements of the tables or only selected sets of tables: and in its entirety the corpus consists of about 200 pages of tables, most of which contain 180 entries. The tables are generally rather accurately computed and are all based on lbn Yūnus' values of 30:0°for the latitude of Cairo and 23;35°for the obliquity of the ecliptic.

The main tables in the corpus display the time since sunrise, the time remaining to midday, and the solar azimuth as functions of the solar altitude and solar longitude. Entries are tabulated for each degree of solar altitude and longitude, and each of the three sets contains over ten thousand entries. The remaining tables in the corpus are of spherical astronomical functions, some of which relate to the determination of the five daily prayers of Islam.

The times of Muslim prayer are defined with reference to the apparent daily motion of the sun across the sky and vary throughout the year. The prayers must be performed within certain intervals of time, which are variously defined. The following general definitions underlie the tables in the corpus. The day is considered to begin at sunset, and the evening prayer is performed between sunset and nightfall. The permitted interval for the night prayer begins at nightfall. The interval for the morning prayer begins at daybreak and the prayer must be completed by sunrise. The period for the noon prayer begins when the sun is on the meridian, and that for the afternoon prayer begins when the shadow of any object is equal to its midday shadow plus the length of the object.

Examples of functions relating to the prayer times, which are tabulated in the corpus for each degree of solar longitude, include the following:

1. The length of morning and evening twilights, defining the permitted times for the morning and evening prayers, based on the assumption that twilight appears or disappears when the sun reaches a particular angle of depression below the horizon. (The angles suggested by Ibn Yūnus in the *Hākinuī zīj* are 18° he suggests 20°and16° for morning and evening, respectively. The main twilight tables in the corpus are based on 19°and 17°.)

2. The time from nightfall to daybreak, defining the permitted interval for the night prayer.

3. The time from sunrise to midday.

4. The time from midday to the beginning of the time for the afternoon prayer, defining the interval for the noon prayer; and the time from the beginning of the afternoon prayer to sunset, defining the interval for the afternoon prayer.

5. Corrections to the semidiurnal arc for the effect of refraction at the horizon, apparently based on the assumption that the true horizon is about 2/3° below the visible horizon. (These corrections, which are specifically attributed to Ibn Yunus, represent the earliest attested quantitative estimate of the effect of refraction on horizon phenomena.)

6. The solar altitude in the azimuth of Mecca, and the time when the sun has this azimuth. (Such tables were used to establish the direction of prayer and the orientation of *mihrābs* in mosques.)

Virtually all later Egyptian prayer tables until the nineteenth century were based on those in this main corpus. In certain cases the original tables were well-disguised, the entries being written out in words for each day of the Coptic year or a given Muslim year. The impressive developments in astronomical timekeeping in thirteenth-century Yemen and fourteenth-century Syria. particularly the tables of Abuʿl-ʿUqul for Taʿizz and of al-Khalīlī for Damascus, also owe their inspiration to the main Cairo corpus.

It is clear from the biography of Ibn Yunus by his contemporary al-Musabbihī, preserved in the writings of later authors, that Ibn Yūnus was an eccentric. Al-Musabbihī describes him as a careless and absentminded man who dressed shabbily and had a comic appearance. One day, when he was in good health, he predicted his own death in seven days. He attended to his personal business, locked himself in his house, and washed the ink off his manuscripts. He then recited the Koran until he died-on the day he had predicted. According to his biographer, Ibn Yunus' son was so stupid that he sold his father's papers by the pound in the soap market.

BIBLIOGRAPHY

I. Original Works. Ibn Yūnus' works are the following:

1. *al-Zī/ al-Hākimī al-kabīr*: MS Leiden Cod. Or. 143 for both phenomena, but in a later work contains chs. 1-22; MS Oxford Hunt. 331 contains chs. 21-44 ; MS Paris B.N. ar. 2496 is an anonymous abridgment containing some additional chs. up to 57 and chs. 77-81 ; MS Leiden Cod. Or. 2813 contains part of ch. 1. Extracts from Ibn Yūnus' gmean motion tables are in numerous later sources, such as MS Princeton Yahu-da 3475, fols. 16r-21r; and MS Cairo Dar al-Kutub, inigat 116M.

2. Other *zījes* are not extant. A treatise on the compilation of solar, lunar, and planetary ephemerides, which appears to be taken from a *zīj* by Ibn Yunus other than the *Hākimi*, survives in MS Cairo Dar al-Kutub, *mīgāt* 116M, fols. 8v-9r; and probably in MS Berlin Ahlwardt no.5742, pt. 2. A fragment of an Egyptian *zīj* containing tables due to Ibn Yunus is MS Berlin Ahlwardt 5733. The late thirteenth-century Yemenite *Mukhtār zīj*, extant in MS British Museum 768 (Or. 3624), appears to be based on a *zīj* by Ibn Yūnus compiled prior to the *Hākimī zīj*.

The following *zījes* are incorrectly attributed to Ibn Yūnus on their title folios: MS Aleppo Awqāf 947: MS Cairo Tal'at, *mīgāt* 138; MSS Paris B.N. ar.2520 and 2513. The first two are quite unrelated to the Egyptian astronomer. The two Paris MSS are copies of the thir-teenth-century Egyptian *Mustalah zīj* and a later recension: they both contain material due to Ibn Yūnus. Two treatises purporting to be commentaries on a zij by lbn Yūnus-MS Gotha Forschungsbibliothek A1401 and MS Cairo Dār al-Kutub, mīgat 1106-are based on the *Mustalah zīj*.

Short notices on topics in spherical astronomy attributed to Ibn Yunus are in MS Milan Ambrosiana 281e (C49) and MS Paris B.N. ar. 2506.

3. *Kitāb ghāyat al-intifā*' ("Very Useful Tables," a later title given to the corpus). The following sources contain most of the tables : MS Dublin Chester Beatty 3673 and MS Cairo Dār al-Kutub, mīqāt 108.

Ibn Yūnus' original solar azimuth tables, entitled *Kitāh al-samt*, are extant in MS Dublin Chester Beatty no. 3673, pt. I; MS Gotha Forschungsbibliothek no. A1410, pt. 1: MS Cairo Dar al-Kutub, *mīgāt* 137M; and MS Cairo Azhar *falak* no. 4382, pt. 2.

The tables of time since sunrise, entitled Kitab *aldā'ir* and associated with al-Magsī (*fl*. 1275), are in MS Gotha Forschungsbibliothek A 1402 . The hourangle tables and numerous prayer tables in the version by lbn al-Kattānī (*fl*. 1360) are preserved in MS Istanbul Kilic Ali PŠsa 684. The hour-angle tables, entitled *Kitāb fadl! al-dāʿir*, are copied separately in MS Cairo Taymūriyya, *riyādiyyāt* 191; and MS Cairo Azhar, falak no. 4382, pt. 1; they are copied together with the tables of time since sunrise in MS Dublin Chester Beatty no. 3673, pt. 2; and MS Dublin Chester Beatty 4078. The edition of the corpus by al-Bakhanigi (*ft*. 1350) is extant in MS Cairo Dar al-Kutub, *mīgāt* 53 and 108.

There are literally dozens of MSS that contain extracts from the corpus in varying degrees of confusion.

MSS Cairo Taymūriyya, *riyādiyyāt* 354; and Dār alKutub, *mīgāt* 1207, together constitute a corpus of tables for timekeeping computed for the latitude of Alexandria. In the first the tables are falsely attributed to Ibn Yunus.

4. *Kitāb al-zīj* (sine tables) are extant in MS Berlin Ahlwardt no. 5752, pt. 1; and MS Damascus Zāhiriyya 3109.

5. *Kitāb al-zill* (cotangent tables) apparently are not extant. The tangent tables in MS Berlin Ahlwardt no. 5767, pt. 3, attributed to Ibn Yunus are not based on the cotangent tables in the Hākimi zīj.

6. *Kitāb al-mayl* (solar declination tables) are MS Berlin Ahlwardt 5752,2.

7. *Kitāb al-ta'dil al-muhkam* (solar and lunar equation tables) are extant in MS Cairo Dār al-Kutub, *mīgāt* 29, which contains the complete set of lunar tables : MS Gotha Forschungsbibliothek no. A 1410, pt. 2, which contains an incomplete set; and MS British Museum Or. 3624, fols. 11ly-129r, I13v-151r, which contains the solar tables and a related set of lunar tables .

8. A short treatise on a candle clock is in MS Beirut St. Joseph, Arabe 223/12. This is attributed to Ibn Yunus al Misrī (the Egyptian) in the introduction but is attributed by the Syrian engineer al-Jazari f *(ft*.ca. 1200) to Yunus al-Asturlābī (the astrolabe maker), who may not be identical with the celebrated Egyptian astronomer. On the clock itself, see E. S. Kennedy and W. Ukashah, "The Chandelier Clock of Ibn Yunis," in Isis, **60** (1969), 543-545.

9. *Kitāb bulūgh al-umniyya fi mā yataʿallaq bitulūʿ al-Shiʿrā l-yamāniyya* (astrological treatise) is in MS Manchester Mingana 927 (916): MS Gotha Forschungs-bibliothek A1459; and MS Cairo Dār al-Kutub, *majāmī*'289.

10. The poem on the times of prayer attributed to Ibn Yunus in MS Cairo Dār al-Kutub, *mīqāt* 181M, fols. 46v-48r, also occurs in two corrupt versions attributed to the Imām al-Shāfi 'ī in MSS Berlin Ahlwardt 5700, fol. IIr, and 5820, fol. 65r. Poems by lbn Yunus are found in several medieval Arabic anthologies.

II. Secondary Literature. Early Studies of the *Hākimī zīj* are A. P. Caussin de Perceval, "Le livre de la grande table Hakémite," in *Notices et extraits des manuscrits de la Bibliotheque nationale*, **7** (1804), 16-240, on the observation accounts; and J .-B. Delambre, *Histoire de l'astronomie du moven âge* (Paris, 1819, repr. New York-London, 1965), containing a summary of the contents of the *Zīj*. The major studies by Carl Schoy on Ibn Yūnus are his "Beiträage zur arabischen Trigonometrie" in *Isis*, **5** (1923), 364-399; Gnomonik der Araber, which is I, pt. 6, of E. von Bassermann-Jordan, ed., *Die Geschichte der Zeitmessung and der Uhren* (Berlin-Leipzig, 1923); and *Über den Gnomonschatten and die Schattentufehr der arabischen Astronomic* (Hannover, 1923). Articles by Schoy on individual chapters of the *Hākimī zīj* were published in *Annalen der Hvdrographie and maritimen Meteorologie*, **48** (1920), 97-111; **49** (1921), 124-133; and **50** (1922), 3-20, 265-27 I. A more recent study of the spherical astronomy in the *Hākimī zīj* is D. A. King. "The Astronomical Works of Ibn Yūnus" (Ph .D. diss., Yale University, 1972). The tables entitled Kitab al-taʿdil al-muhkam are discussed in D. A. King, "A Double-Argument Table for the Lunar Equation Attributed to Ibn Yunus" in Centaurus, **18** (1974), 129- 146.

On the observatories in medieval Cairo, see A. Sayili. The Observatory in Islam (Ankara, 1960), 130- 156, 167- 175.

For modern studies relying on data from Ibn Yūnus' observational accounts, see S. Newcomb, "Researches on the Motion of the Moon. Part I." in Washington Observations for **1875** (1878), app. 2; and R. Newton, Ancient Astronomical Observations and the Acceleration of the Earth and Moon (Baltimore, 1970).

On the corpus of spherical astronomical tables for Cairo attributed to Ibn Yūnus, see D. A. King, "Ibn Yūnus' Very Useful Tables for Reckoning Time by the Sun" in Archive for History of Exact Sciences, **10** (1973), 342-394. The problems of their attribution, and all other known medieval tables for regulating the times of prayer, are discussed in D. A. King, Studies on Astronomical Timekeeping in Medieval Islam, which is in preparation.

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