Al-khalili, Shams Al-din Abu¯ ‘Abdallah Muh?ammad Ibn Muh?ammad | Encyclopedia.com

(*fl*. Damacus, Syria,ca.1365)

astronomy, mathematics.

Al-Khalīlī (suter,no,418)was an astronomer associated with the Umayyad Mosque in the center of Damascus. A colleague of the astronomer Ibn al-Shātir, he was also a *muwaqqit*–that is,an astronomer concerned with *ʿilm al-mīqāt*, the science of timekeeping by the sun and stars and regulating the astronomically defined times of Muslim prayer. Al-Khalīlī’s major work which represents the culmination of the medieval Islamic achievement in the mathematical solution of the problems of spherical astronomy, was a set of these tables for astronomical timekeeping. Some of these tables were used in Damascus until the nineteenth century, and they were also used in Cairo and Istanbul for several centuries. The main sets of tables survive in numerous manuscripts, but they were not investigated in modern times until the 1970’s.

Al-Khalīlī’s tables can be categorized as follows; tables for reckoning time by the sun, for the latitude of Damascus; tables for regulating the times of Muslim prayer,for the latitude of Damascus; tables of auxiliary mathematical functions for timekeeping by the sun for all latitudes; table displaying the *qibla*, that is, the direction of Mecca,as a function of terrestrial latitude and longitude; and tables for converting lunar ecliptic coordinates to eqatiorial coordinates.

The first two sets of tables correspond to those in the large corpus of spherical astronomical tables computed for Cairo that are generally attributeed to the tenth-century Egyptian astronomer Ibn Yūnus. They are recomputed for Ibn al-Shātir’s parameters; 33;30° for the latitude of Damascus and 23:31° for the obliquity of the ecliptic. Al-Khalīlī does not mention any of his Egyptian predecessors. We know, however, that an elder colleague of his, the instrument maker al-Mizzī (*d.ca*.1350;Suter no.406), who spent the first part of his life in Egypt and then moved to Damascus, had already compiled a set of hour-angle tables and prayer tables similar to those used in Egypt and based on 33;27° for the latitude of Damascus and 23:33° for the obliquity, a pair of parameters used by earlier Syrian astronomers. Al-Khalīlī’s first and second tables were thus intended to replace al-Mizzī’s set. These tables were used in Damascus until the nineteeth century. The Damascus *muwaqqit* Muhammad ibn Mustafā al- Tanatāwi, who died in 1889, was one of the last to use them; he also converted the entries from equatorial degrees and minutes to equinatial hours and minutes.

The third set of tables compiled by al-Khalīlī consisted of auxiliary tables for timekeeping by the sun and a table of the solar azimuth as a function of the solar meridian altitude and instantaneous altitude. The auxiliary tables, which contain over 9,000 entries, are intended specifically for facilitating the computation of the hour angle for given solar altitude,and solar longitude, and any terrestrial latitude. They were plagiarized by later astronomers in both Egypt and Tunis.

Al-Khalīlī’s fourth set of tables was designed to solve all the standard problems of spherical astronomy, and they are particularly useful for those problems that, in modern terms, involve the use of the cosine rule for spherical triangles. Al-Khalālī tabulated three functions and gave detailed instructions for their application. The functions are the following(the capital notation indicates that the medieval trigonometric functions are computed to base R=60, thus Sin ϑ = R Sin ϑ, and so on):

and

computed for the domains

ϑ= 1°,2°,…, 90°

ϕ= 1°,2°,…, 55°, as well as 21;30°(Mecca) and 33;30°(Damascus)

x=1, 2, … ,59

y=0°, 1°,… ,n(x)

where *n(x)* is the largest integer such that

R $x \leq$ Cos n(x).

The entries in these tables, which number over 13,000, were computed to two sexagesimal digits and are invariably accurate. An example of the use of these functions is the rule outlined by al-Khalili for finding the hour angle t for given solar or stellar altitude h, declination $, and terrestrial latitude This may be represented as and it is not difficult to show the equivalence of al-Khalīlī's for finding the hour angle *t* for given solar or stellar altitude *h,* declination δ, and terrestrial latitudeø.This may be represented as

$t(\text{h},\delta,\phi) = \text{G}\{[f_{\phi}(\text{h})\text{-g}_{\phi}(\delta)],\delta\}$,

and it is not difficult to show the equivalence of al-Khalīlī's rule to the modern formula

These auxiliary tables were used for several centuries in Damascus, Cairo, and Istanbul, the three main centers of astronomical timekeeping in the Muslim world.

Al-Khalīlī's computational ability is best revealed by his *qibla* table. The determination of the qibla for a given locality is one of the most complicated problems of medieal Islamic trigonometry. If (L,ϕ)and (L_M,ϕ_M) represent the longitude and latitude of a given locality and of Mecca,respectively, and $\Delta L = |L - L_M|$,then the modern formula for q(L, ϕ), the direction of Mecca for the locality, measured from the south, is

Al-Khalīlī computed q(ϕ,L)to two sexagesimal digits for the domains ϕ=10°,11°,…,56°(also 33;30°)and ΔL=1°,2°,…,60°; and the vast majority of the 2,880 entries are either accurately computed or in error by±0;1° or ±0;2°. He states that he used the method for finding the qibla expounded by the late thirteenth-century Cairo astronomer Abū ʿAli al-Marrākushi (Suter. no. 363); and it seems that he used his universal auxiliary tables to compute the qibla values, although they are generally more accurate than can be derived from the auxiliary tables in their present form. Several other qibla tables based on approximate formulas are known from the medieval period. Al-Khalīlī's table does not appear to have been widely used by later Muslim astronomers.

The last set of tables known to have been compiled by al-Khalīlī is for converting lunar ecliptic coordinates to equatorial coordinates, in order to facilitate computations relating to the visibility of the lunar crescent.

Al-Khalīlī wrote at least one treatise on the use of the quadrant with a trigonometric grid (*al-rub ʿal-mujayyab*), but his writings on this instrument have not yet been studied.

BIBLIOGRAPHY

I. Original Works. MS Paris B.N. ar. 2558, copied in 1408, contains all of the tables in al-Khalīlī's major set (nos. 1, 2, 4, and 5). MS Berlin Ahlwardt 5753-6(Wetzstein 1138) contains all but the hour-angle tables, MS Oxford Bodleian Seld. sup. 100 contains the prayer tables and the hour-angle tables; MSS Oxford Marsh 39 contains the hour-angle tables. MSS Oxford Marsh 95 and Escorial ar. 931 contain only the universal auxiliary tables; and MS Gotha Forschungsbibliothek A1406, only the prayer tables. MSS Damascus Zāhiriyya 3116 and 10378 also contain tables from the corpus. MS Cairo Talaat mīqāt 228 contains al-Khalīlī's universal auxiliary tables and hour-angle tables for Damascus, as well as an anonymous set of prayer tables for the latitude of Tripoli (Lebanon). MS Cairo Dār al-Kutub *mīqīt* 71M contains al-Khalīlī's tables of the hour angle and time since sunrise, plus tables of the solar azimuth computed by al-Halabīīi (*d*. 1455; Suter, no. 434). Egyptian copies of the auxiliary tables exist in MSS Princeton Yahuda 861, 2 and Cairo Dār al-Kutub *mīqāt* 43M. MS Istanbul Aya Sofya 2590 consists of a recension of the auxiliary tables by the Ottoman astronomer Muhammad ibn Kātib Sinān (*ca*. 1500; Suter, no, no 455). Al-Tantāwī's prayer tables and hour-angle tables are extant in MSS Damascus Zāhiriyya 9233, and Cairo Taymūr *riuādiyyāt*129 and Dār al-Kutub *mīqāt* 1007.

MS Dublin Chester Beatty 4091 is an apparently unique copy of al-Khalīlī's auxiliary tables for timekeeping by the sun and azimuth tables. Later Egyptian and Tunisian copies of the auxiliary tables are MSS Cairo Dār al-Kutub *mīqāt* 644 and Istanbul S. Esad Ef. Madresesi 119,2 and MS Cairo Dār al-Kutub *mīqāt* 689, respectively.

Al-Khalīlī's tables for crescent visibility are in the treatise entitled ʿ *lqd al-durar*, by the later Egyptian astronomer Ibn al-Majdi (Suter, no. 432), and his criteria for crescent visibility are outlined in the writings of his nephew Sharaf al-Dīn al-Khalīlī (Suter, no. 427).

Al-Khalīlī's treatise on the quadrant with trigonometric grid is in MSS Cairo Dār al-Kutub *mīqāt* 138,9 and 201M. Another treatise of considerable interest on the same subject, preserved in MS Cairo Dār al-Kutub *mīqāt* 167M,8, may be by al-Khalīlī. A treatise describing a horizontal sundial is attributed in MS Princeton Yahuda 373, fols. 131v-135r, to Abū ʿAbd Allāh al-Khalīlī, and in MS Manchester 361G to the later Egyptian astronomer 'ʿAbd al-ʿAzīz ibn Muhammad al-Wafāʾī (Suter, no. 437).

II . Secondary Literature. See D. A. King, “AlKhalīlī’s Auxiliary Tables for Solving Problems of Spherical Astronomy,” in *Journal for the History of Astronomy*, **4** (1973), 99-110; and “Al-Khalīlī’s *Qibla*Table,” in *Journal of Near Eastern Studies*, **34** (1975), 81-122; and H.Suter, *Die Mathematiker and Astronomen der Araber und ihre Werke*(Leipzig, 1900), 169.

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