

On the Early History of the Universal Astrolabe in Islamic Astronomy, and the Origin of the Term "Shakkāziya" in Medieval Scientific Arabic

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FOR SOME YEARS I have been interested in the origin of the name of a medieval Islamic astronomical instrument, the *ṣaḥīḥa shakkāziya*.¹ My interest was first aroused by a remark of Prof. Willy Hartner, who, in his valuable study of the astrolabe stated: "another early variety of Al-Zarqālī's astrolabe is the *ṣaḥīḥa shakkāziyya* (or *shakāziyya*), about which we do not yet possess any accurate information."²

The term *shakkāziya* relates to a grid as shown in Plate 1. The *ṣaḥīḥa* of al-Zarqāllū (*fl.* Toledo and Cordova, died *ca.* 1090)³ consists of two such grids superimposed on a single plate at an angle equal to the obliquity of the ecliptic: see Plate 2. Al-Zarqāllū is known to have proposed such a double *shakkāziya* grid with a special alidade, and this is generally accepted as a simplification of the universal astrolabe of the contemporary Toledo scholar Abu'l-Ḥasan 'Alī ibn Khalaf ibn Aḥmar (?) al-Ṣaydalānī (= the apothecary).⁴ Ibn Khalaf

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2. Hartner, p. 317 (reprinted from *EI*₂, I, p. 727). (Italicized abbreviations are references to the bibliography).

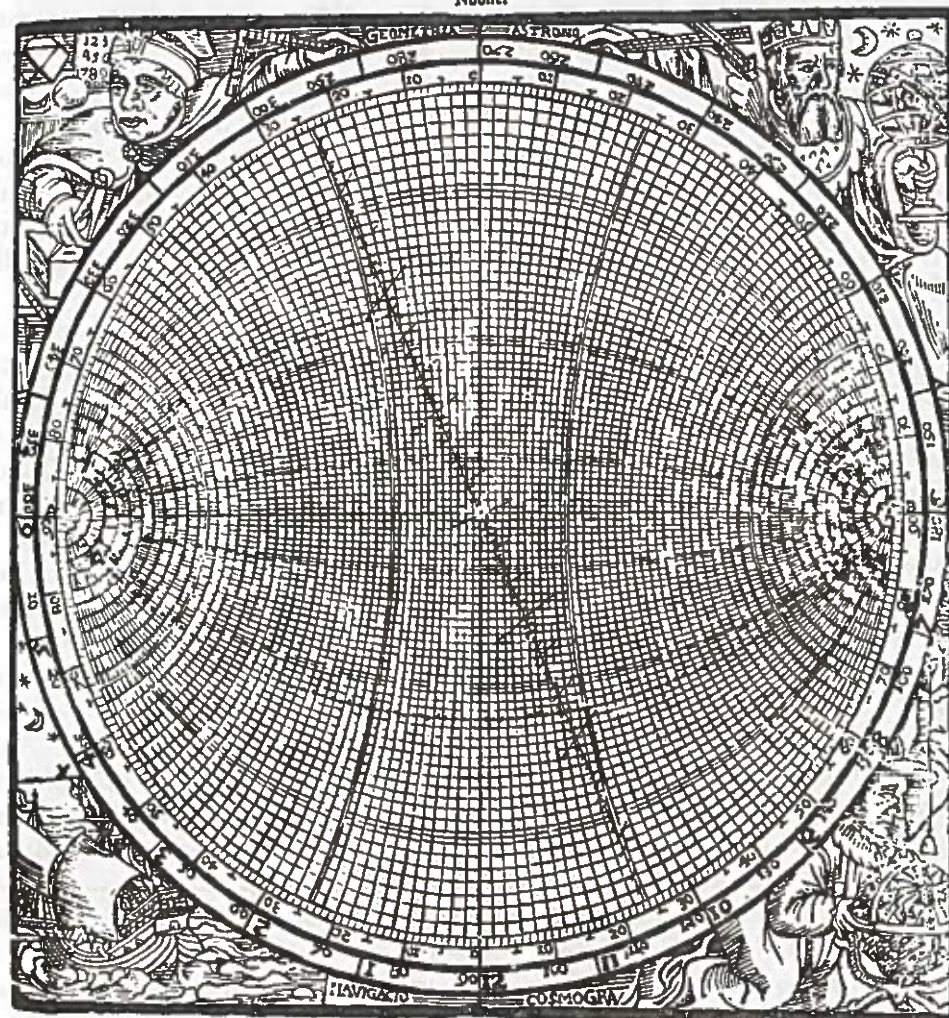
3. On al-Zarqāllū see the article "al-Zarqālī" in *DSB* by J. Vernet and the references there cited, especially the various studies of J. Millás Vallicrosa.

4. 'Alī ibn Khalaf's treatise is in *Libros del Saber*, III, pp. 1-132, and has been discussed in Millás 1, 2, and 3. On the identity of the author see especially Millás 2, pp. 443-446 and 3, pp. xxx-xxxvi, and also Vera, pp. 93-95. 'Alī ibn Khalaf's instrument is generally overlooked in modern studies of the astrolabe: thus, for example, it is not mentioned at all in Michel, and the only account of it in

MARGARITA MATHEMATICA. *Astronomis nobilissimum, Geometris iucundissimum, Navigantibus prefatissimum, Cosmographis commodissimum, Philosophis, Medicis, & aliisq; sublimis affectantibus gratissimum, Tyronebusq; facillimum.*

The handle is borne to be set on.

Meridies.
Noont.



Media nox.
North.

Pec Ioannem Blagravum Readingensem, conditum, editum, & Sculptum.

1584.

Plate 1: A *shakkāziya* plate illustrated in the treatise of John Blagrave of Reading published in 1584 and dealing with a universal astrolabe of the kind invented by 'Alī ibn Khalaf.

(Courtesy R. Webster, Adler Planetarium, Chicago)

is mentioned along with al-Zarqāllu in the eleventh-century biographical work entitled *Ṭabaqāt al-umam* by Šāʿid al-Andalusī (born Almeria, 480/1029, fl. Toledo, died 456/1064).⁵ His astrolabe, which is known only from the description in the thirteenth-century *Libros del Saber*, bears a rete, shown in Plate 3, part of which is a semicircle of *shakkāziya* curves. This rotates over a *shakkāziya* plate, and with such a device, problems of spherical astronomy, which are essentially problems of conversion of coordinates on the celestial sphere, can be solved with facility for any latitude. Al-Zarqāllu proposed an alidade fitted with a perpendicular rule, shown in Plate 4, to replace the rete of Ibn Khalaf's astrolabe, and both devices can be used toward the same end, namely, the solution of problems of spherical astronomy for all latitudes. Since Ibn Khalaf's rete for his universal astrolabe also included a projection of the ecliptic and the fixed stars, his instrument is superior to al-Zarqāllu's plate and alidade.⁶

In later Islamic astronomy Ibn Khalaf's astrolabe was apparently not known outside Andalusia, but both the *ṣafiha shakkāziya*, with one set of *shakkāziya* markings, and the *ṣafiha zarqālliya*, with two sets, were popular, and there are several later treatises in Arabic, Persian, and Turkish, on the use of one or the other.⁷ In some recent publications Profs. J. Samsó Moya and M. A. Catalá have drawn attention to a *shakkāziya* quadrant, and I have discussed a double *shakkāziya* quadrant. All of our studies were based on fourteenth- and fifteenth-century Syrian and Egyptian sources.⁸ In none of these treatises on the universal astrolabe or quadrant currently known to me is there an indication of the origin of the mysterious word *shakkāziya*.

Prof. Samsó has collected various references to the epithet *shakkāz*, "bleacher of hides", and to a quarter in medieval Toledo where such people worked.⁹ One could infer that the originator of the single plate bearing this grid was called al-Shakkāz, so that his plate was called *al-ṣafiha al-Shakkāziya* and the subsequently-developed quadrant was called *al-rubʿ al-Shakkāzī* or *rubʿ al-Shakkāziya*, both of which are attested. This derivation must be considered as a serious possibility. To support Prof. Samsó's thesis I can cite one medieval text which implies that the term *shakkāzī* relates to the name of the individual who invented the grid. In a treatise on the use of the *shakkāziya* grid by an astronomer named ʿAbd Allāh ibn Muḥammad al-Tujībī (on whom we have

the recent literature is in Maddison-Turner (preprint), pp. 123-125. Likewise, ʿAlī ibn Khalaf himself is omitted from Suter and Brockelmann.

5. Cf. Šāʿid al-Andalusī, ed., p. 75, and trans., pp. 138-139. See also note 16 below.

6. Cf. J. Vernet in his article "al-Zarqālī" in *DSB*, where it is suggested that al-Zarqāllu's plate is an instrument superior to that of ʿAlī ibn Khalaf.

7. A survey of Islamic writings on universal astrolabes and quadrants is in preparation.

8. Cf. Samsó 1, 2, and 3; Samsó-Catalá; and King 1.

9. Samsó 3, p. 187.

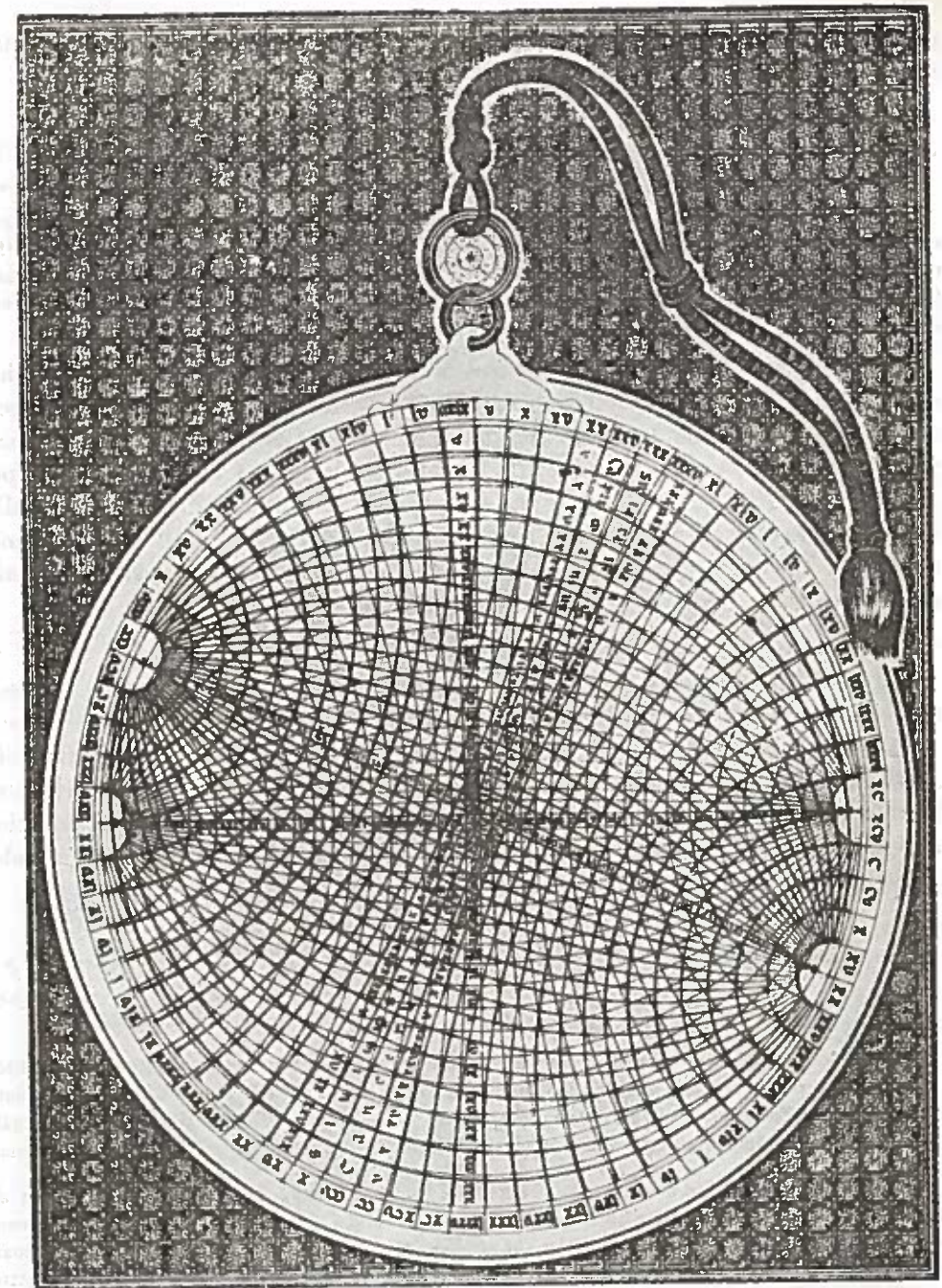


Plate 2: A *zarqālliya* plate illustrated in the *Libros del Saber*.

(Courtesy Harvard University Library and Owen J. Gingerich)

no biographical information) extant in the unique copy MS Cairo Taymūr riyāda 159,1 (pp. 1-61, copied 1320H!), we read:

... وبعد فاني لما رايت الناس في الحديث والقديم قد وضعوا على الآلات الاوقائية رسائل كثيرة لا سيما على الاسطرلاب ولا وضع احد منهم على احد الصفيحتين رسالة اعنى صفيحة الشيخ ابي اسحاق ابراهيم الطليطل شهر بالزرقالي رحمه الله والصفيحة المنسوبة للشكازي وهما مع ذلك احسن الآلات لعمومهما في جميع العروض ...

... When I saw that people in former times and recently had prepared many treatises on instruments for timekeeping, especially on the astrolabe, but no one had prepared a treatise on either of the two *ṣafiḥas*, I mean the *ṣafiḥa* of Shaykh Abū Ishāq Ibrāhīm of Toledo, known as al-Zarqāllu, may God have mercy upon him, and the *ṣafiḥa* attributed to al-Shakkāzī, and since these two instruments are nevertheless the best ones because of their universality...

If al-Tujībī thought so much of al-Shakkāzī's *ṣafiḥa* it is curious that he did not invoke God's mercy on al-Shakkāzī as well as on al-Zarqāllu. I suspect that al-Tujībī was not too sure about the identity of al-Shakkāzī. In the treatise on the single *shakkāziya* quadrant by the early fourteenth-century Aleppo astronomer 'Alā' al-Dīn Ṭibughā al-Dawadār al-Baklamshī, extant in MS Cairo Dār al-Kutub *miqāt* 774 (14 fols., copied 864H),¹⁰ we find already some confusion between the personal name al-Shakkāzī and the instrument *al-shakkāziya*:

[See the note added in proof on p. 255]

اما بعد فقد تقدم وضع الاصطرلاب المغني في الاعمال النجومية بكل العروض الافاقية المستبط من الزرقالي والشكازية...

... There has already been made a universal (*mughnī* = dispensing with plates for different latitudes) astrolabe for solving astronomical problems for all latitudes, invented by al-Zarqāllu and *al-shakkāziya*...

I shall now present three new sources which seem to indicate that *al-shakkāziya* is a corruption of another word. We begin with MS Escorial ar. 962 (82 fols., copied ca. 700H?) of al-Zarqāllu's treatise in 100 chapters on the use of his *ṣafiḥa*. In the colophon of this particular copy of his treatise (fols. 81v-82r)¹¹ we read the following onte:

... كل كتاب الشيخ الاجل العلامة ابي اسحاق المعروف بالزرقالي في الصفيحة العامة لعروض البلدان والافاق وهي التي صنعها اخرا بعد معارضة ابي الشجار له في الاولى باخرا عملها وصنع فيها شبكة فادى ذلك الى عمل هذه وصلى الله على سيدنا محمد ...

which seems to mean (free translation):

The book of ... al-Zarqāllu of the plate which is universal for all latitudes and horizons is finished. This is the plate which he constructed finally (?) after Abu'l-Shajjār had made another plate similar to al-Zarqāllu's first plate but on which he had constructed a rete. This led to al-Zarqāllu's making the instrument described in this treatise. May God bless and save our Lord Muhammad,

10. On al-Baklamshī see Brockelmann, II, p. 135, and SII, p. 167. Ḥājji Khalifa states that al-Baklamshī invented the *Shakkāziya* quadrant (see *Samsó-Catalá*, pp. 7 and 11), by which is meant that he was (perhaps) the first to consider the solution of problems of spherical astronomy approximately using a quadrant of *shakkāziya* curves and a thread attached at the centre. The treatise attributed to Ibn Ṭibughā preserved in MS Cairo Dār al-Kutub *miqāt* 64,4, fols. 63v-73v, copied 803H, which is considered in *Samsó-Catalá*, may be by 'Alī ibn Ṭibughā, a *muwaqqit* of Aleppo who was perhaps the son of al-Baklamshī. Another copy of the treatise by Ṭibughā al-Baklamshī himself is MS Princeton Mach 4912 = Yehuda 373, fols. 149v-157v, copied 1060H.

11. Cf. Renaud, p. 501.

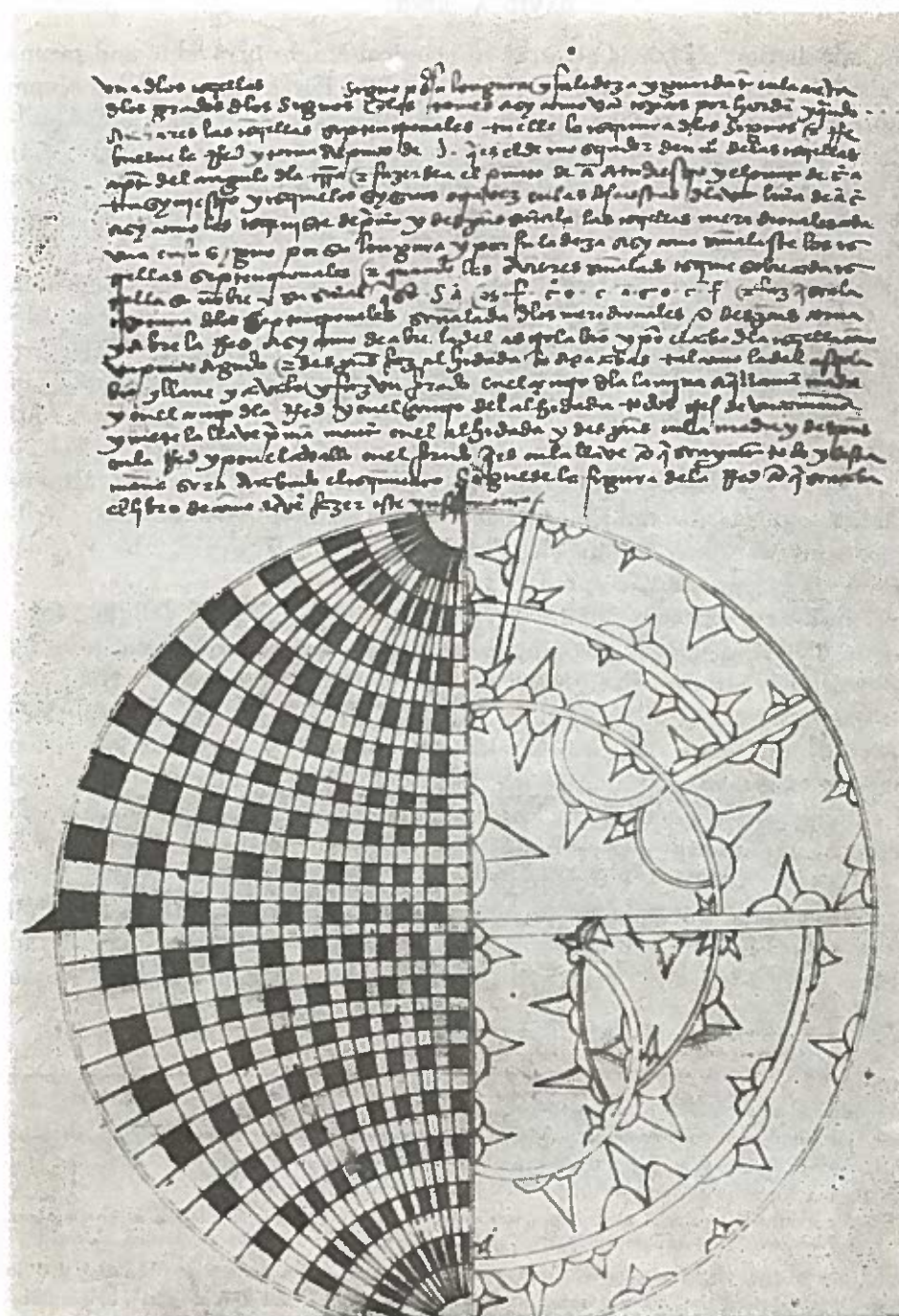


Plate 3: The rete of 'Alī ibn Khalaf's universal astrolabe illustrated in MS Madrid Biblioteca Nacional L 97.

(Courtesy Biblioteca Nacional, Madrid)

The appellation *shajjār* is attested in classical Maghribi Arabic and means "botanist" in the modern sense of "herbalist."¹² For reasons which become apparent below, I think that Ibn al-Shajjār is more likely than the Abu'l-Shajjār which occurs in the text. Nevertheless, this text seems to imply that al-Zarqāllu wrote an early treatise on his plate, that Abū/Ibn'l-Shajjār added a rete to this plate, and that al-Zarqāllu was thereby prompted to write his treatise in 100 chapters.

A second source for our study is the unique copy of the *Zij* of Ibn Ishāq, an astronomer of thirteenth-century Tunis, recently rediscovered in MS Hyderabad Andra Pradesh State Central Library 298 (440 pp., copied ca. 800H).¹³ This work is a valuable new source for the history of astronomy in the Maghrib. In a list of earlier observers Ibn Ishāq lists two individuals 'Alī al-Shajjār and Ibn Wāfid as astronomers who made observations in Toledo in 477 Hijra (= 1084-85). From this information, we learn that Abū/Ibn al-Shajjār was named 'Alī and that he collaborated with Ibn Wāfid, who is well-known for his work on pharmacology and medicine.¹⁴ However, Ibn Wāfid's date of death is generally accepted as 1075 A. D.

Our third new source is MS Leiden Universiteitsbibliotheek 468 (282 fols., copied ca. 750H), a unique incomplete copy of a treatise on timekeeping by an unidentified early-fourteenth-century Egyptian astronomer.¹⁵ Here the author quotes a version of Sā'id al-Andalusī's *Ṭabaqāt al-umam*, and mentions (fol. 88r) Abu'l-Ḥasan 'Alī ibn Khalaf ibn Khyr (!) al-Ṣaydalānī (written without diacritical marks) along with al-Zarqāllu as a scholar of Toledo and as a distinguished geometer (here the name is simply al-Ṣaydalānī although actually the manuscript has al-Ṣandalānī). However, later in the text (fol. 90v), our author quotes a different work by Sā'id al-Andalusī entitled *Kitāb Ṭabaqāt al-ḥukamā'*,¹⁶ and states that al-Zarqāllu wrote a treatise in 100 chapters on an instrument called the *zarqālliya* which he invented around 440 Hijra (=1048-49), and that Abu'l-Ḥasan 'Alī ibn Khalaf ibn Akhyr "whom

12. Dozy, I, p. 730.

13. On Ibn Ishāq see Suter, no. 356.

14. On Ibn Wāfid (1008-1075) see the article in DSB by J. Vernet. He was not previously known to have conducted astronomical observations.

15. On this manuscript see Voorhoeve, p. 153. The work is based mainly on the treatise of Abū 'Alī al-Marrākushī (see note 19 below) and the thirteenth-century Egyptian *Muṣṭalah Zij*, but it also contains interesting historical information.

16. On the available works of al-Andalusī see the remarks of R. Blachère in *Sā'id al-Andalusī*, tr., pp. 12-15.

It is of interest that the Egyptian scholar Ibn al-Qifṭī (on whom see the article "Ibn al-Qifṭī" in *EI*₂ by A. Dietrich) used the *Ṭabaqāt al-umam* of Sā'id al-Andalusī, but Ibn al-Qifṭī's biographical dictionary is extant only in a recension in which 'Alī ibn Khalaf is not mentioned. A more careful investigation of the historical and bio-bibliographical material in the Leiden manuscript would be worthwhile, not least because the author adds to his quotes from Sā'id al-Andalusī's works some information on several Egyptian scientists from the thirteenth century whose names are new to the modern literature.

Estas son las figuras de la regla. et dell alhidada dell ostrumento á que llaman la azafaba.

Esta es la regla a que llaman orizon enclimado que tiene ser puesta sobre la faja de la Lamina.

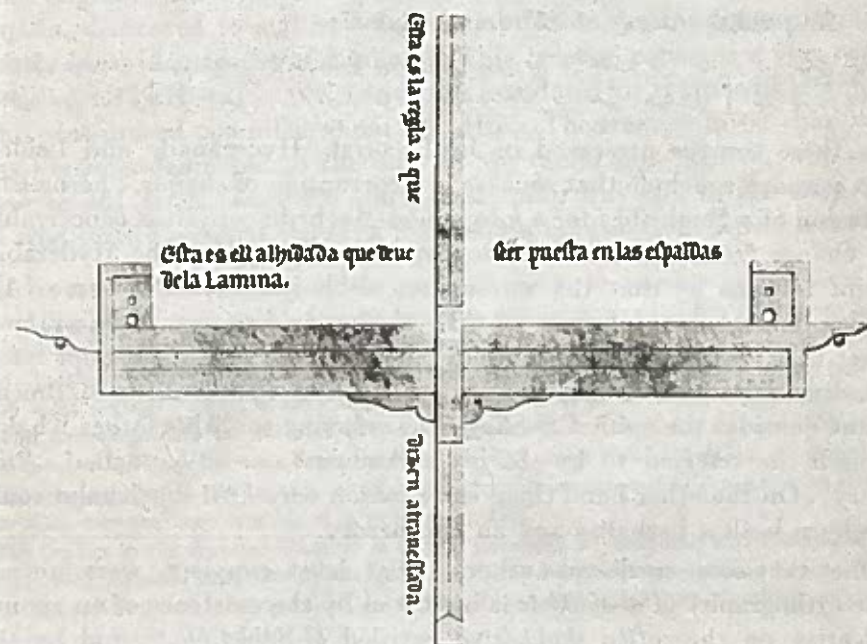


Plate 4: The alidade to be used with al-Zarqāllu's plate, illustrated in the *Libros des Saber*

(Courtesy Harvard University Library and Owen J. Gingerich)

we have mentioned before and who was known as al-Sh'wy" had made an instrument in 464 Hijra (= 1071-72) for al-Ma'mūn, amir of Toledo, which he had called *al-asṭurlāb al-Ma'mūnī*, and which had a universal (set of) horizon(s). The orthography al-Sh'wy is easily conceived as a corruption of al-Shajjār, especially by an Egyptian who might have been influenced by a well-attested name like al-Sakhāwī. The Arabic text reads as follows:

ق ٨٨ و : ... منهم من سكان طليطة وجهاتها ابو الحسن على بن خلف بن اخير [!] الصيدلاني وابو اسحق ابراهيم بن يحيى النقاش المعروف بولد الزرقاد [!] ... وابرعهم في الهندسة الصندلاني [!]

ق ٩٠ ظ : ... ومنهم الفاضل التحرير المتقدم ذكره ابو اسحق ابراهيم الاندلسي الملقب بالزرقالي الذي استنبط الزرقاله [اقرأ : الزرقالية] وصنف في العمل بها مائة باب في حدود سنة اربعين واربع مائة ومنهم ابو الحسن على بن خلف بن اخير [!] المتقدم ذكره ويعرف بالسحاوي صنع آلة للسامون ذي المحدثي [؟] ابي الحسن يحيى بن ذي النون الامير بطليطة من الاندلس بعد انقراض الدولة الاموية ولقبها بالاسطرلاب الماموني ذات الاقاف الشامل سنة اربع وستين واربع مائة هجرية ...

Compare the published text of Šā'id al-Andalusī:

ص ٧٥ و : ... فمنهم من سكان طليطة وجهاتها ابو الحسن على بن خلف بن اخير وابو اسحق ابراهيم بن يحيى النقاش المعروف بولد الزرقال ... وابرع هؤلاء في الهندسة على بن اخير الصيدلاني [انظر ص ١٢٤]

From these sources preserved in El Escorial, Hyderabad, and Leiden, we might perhaps conclude that *shakkāz* is a corruption of *shajjār*, "herbalist". The confusion of a Maghribi *j* for a *k* by a non-Maghribi copyist is conceivable, and the change from *r* to *z* in Arabic requires only a dot. The Hyderabad manuscript informs us that the astronomer al-Shajjār bore the name 'Alī. The Leiden manuscript informs us that al-Shajjār (written *al-Sh'wy*) was none other than 'Alī ibn Khalaf himself. Since the Escorial manuscript refers to this individual as Abu'l-Shajjār it might be that we should read Ibn al-Shajjār and consider the epithet al-Shajjār as referring to 'Alī's father Khalaf. 'Alī himself is referred to by Šā'id al-Andalusī as al-Šaydalānī, "the apothecary". On the other hand there is no reason why 'Alī ibn Khalaf could not have been both a herbalist and an apothecary.

The fact that some medieval authors, or at least copyists, were uneasy about the orthography of *al-shakkāz* is indicated by the existence of an anonymous treatise on the *ṣafiha shakkāziya* entitled *al-Sakkājiya*,¹⁷ and by the fact that in a treatise by an individual named Abu'l-Faṭḥ ibn 'Abd al-Raḥmān al-Danūshirī, the *shakkāzi* quadrant is called *rub' al-shankāziya*.¹⁸ But even Abū 'Alī al-Marrākushī, an astronomer of Moroccan origin who worked in Cairo in the late thirteenth century, used the term *shakkāziya*,¹⁹ which was

17. Extant in MSS Cairo Dār al-Kutub Zakīya 706,1 (fols. 1v-8v, ca. 1100H) and Alexandria Municipal Library D 2052, 1 (fols. 1v-14r, ca. 1150H).

18. Extant in MS Tunis Šadiqiya Ridwān 108 (not examined): cf. Samsó 1, p. 391, and 3, p. 183.

19. Cf. Sédillot-fils, p. 183. On Abū 'Alī al-Marrākushī see Suter, no. 363.

used in all of the known treatises on the instrument thereafter, except for those noted above. When the universal astrolabe was invented again in Aleppo in the early fourteenth century by the astronomer Ibn al-Sarrāj,²⁰ who says he hit upon the idea after contemplating the solution of the problem of determining the hour angle from a celestial altitude with a *shakkāziya* plate, he called the instrument *al-Sarrājiya* after himself. Nevertheless, the idea behind his instrument, illustrated in Plate 5, goes back at least to a herbalist of eleventh-century Toledo.

According to the dates given in the Leiden manuscript al-Zarqāllu wrote his treatise on the *ṣafiha zarqālliya* almost twenty-five years before Ibn Khalaf made his universal astrolabe for al-Ma'mūn. Our source states that Ibn Khalaf actually made an instrument for al-Ma'mūn, but his treatise on its use in the *Libros del Saber* is also dedicated to al-Ma'mūn. Now al-Zarqāllu wrote three separate treatises on his instrument, rather than two as is generally acknowledged. Those in 100 and 60 chapters are well known, and are both now available in the original Arabic; also, a unique copy of a treatise in 80 chapters by al-Zarqāllu, dedicated to a ruler whose name is not specifically mentioned, has recently been identified in Istanbul.²¹ This treatise contains a star catalogue for the year 459 Hijra (= 1067) and thus postdates his treatise in 100 chapters, if this was indeed compiled about 440 Hijra. The treatise in 60 chapters is in some versions dedicated to the amir al-Mu'tamid ibn 'Abbād, who came to power in 461 Hijra (= 1069) when al-Ma'mūn was still in power in Toledo, and who finally wrested Cordova from al-Ma'mūn in 471 Hijra (= 1078). We

20. On Ibn al-Sarrāj see Suter, no. 508 (confused), and on his astrolabe see Gunther, I, pp. 284-285 and Maddison-Turner, no. 61. I have prepared a detailed analysis of this instrument using some medieval treatises on its use: see King 2 for a summary.

21. A unique copy of a treatise in 80 chapters dedicated to a ruler who is not named (probably the Caliph al-Ma'mūn of Toledo) is MS Istanbul Aya Sofia 2671,1 (fols. 1r-75r, 621H). This manuscript, listed in Krause, p. 482, has not been previously identified as a copy of a treatise distinct from the other two (see below). The same Istanbul manuscript contains (fols. 133v-151v, cf. Krause, p. 525, no. 15) a treatise on the planispheric astrolabe which can from internal evidence also be attributed to al-Zarqāllu. See the first note added in proof on p. 255.

The treatise in 100 chapters is extant in several manuscripts, including MSS Escorial 962 (cf. Renaud, p. 101), Istanbul Esat 3804,3 (fols. 123-146, 665H - listed as anonymous in Krause, p. 526), and Cairo Dār al-Kutub miqāt 647 (61 fols., ca. 600H). It was translated into Castilian and included in the *Libros del Saber* (III, pp. 135-237).

Al-Zarqāllu's treatise in 61 chapters is extant in MS Cairo Dār al-Kutub hay'a 40 (54 fols., ca. 950H, anonymous). Two later copies of the same treatise (both entitled *al-Shakkāziya* - cf. King 1, p. 219, note 1) arranged in 60 chapters are MSS Istanbul University Library A4800 and Cairo Taymūr riyāda 131,4. This treatise was translated into Hebrew and Latin (both published in Millás 3) and exerted considerable influence in Europe (cf. Poulle).

Also related to these is an anonymous treatise in 130 chapters extant in MS Leipzig Karl-Marx-Universitätsbibliothek 800 (cf. Millás 2, pp. 447-448). This was either incorporated into or taken from the *Kitāb Jāmi' al-mabādī wa'l-ghāyāt* of Abū 'Alī al-Marrākushī, a compendium on astronomical instruments compiled in Cairo in the late thirteenth century (cf. Sédillot-fils, especially p. 183-184).

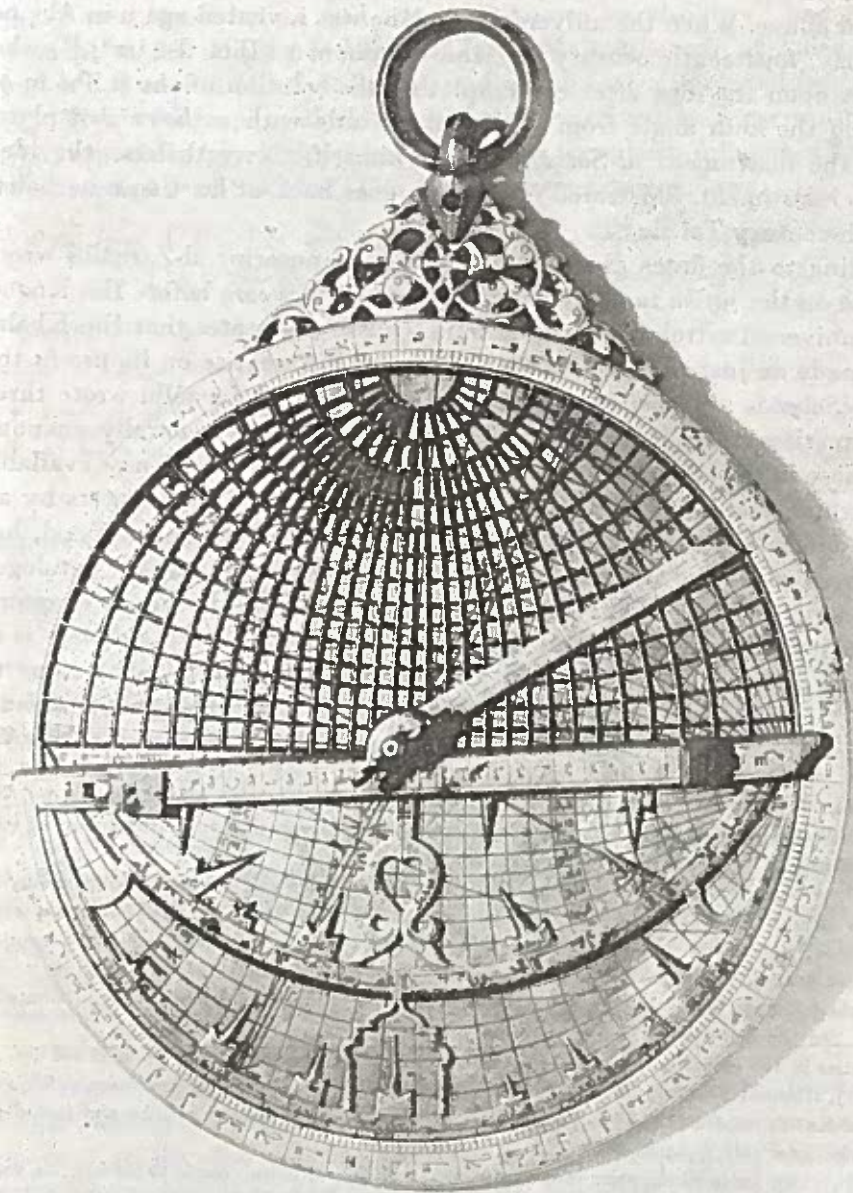


Plate 5: The universal astrolabe of Ibn al-Sarrāj preserved in the Benaki Museum in Athens. This instrument differs from that of ‘Alī ibn Khulaf in that it contains a series of plates and a special trigonometric grid on the back; it is in fact an astrolabe which can be used universally in four different ways. (Courtesy Benaki Museum, Athens)

may presume that shortly thereafter al-Zarqāllu moved from troubled Toledo to Cordova, and that he wrote a new treatise for al-Mu‘tamid to compensate for the fact that he had previously written one, or maybe even two, for al-Mu‘tamid’s rival al-Ma’mūn.

Now that all of al-Zarqāllu’s treatises on his *ṣafiha*, as well as a treatise by him on the planisphaeric astrolabe, are known to exist in the original Arabic, a closer investigation of his works on instruments would be worthwhile. In such an investigation it should be borne in mind that the available evidence does not indicate that the astronomers of Muslim Spain contributed much that was original, and the extent to which al-Zarqāllu might have been influenced by earlier Eastern Arabic sources must remain a matter of speculation. The early ninth-century Damascus astronomer Ḥabash is known to have written on the plate of horizons, to which the single *shakkāziya* plate is closely related.²² His treatise is lost, but another was written by the mid-tenth century scholar of Shiraz, al-Sijzī, and this has recently been located in a unique copy in Damascus.²³ It may eventually be possible to prove that the *shakkāziya* grid is of Greek origin.²⁴ I find it curious that the European name for this plate was “meteoroscope”.²⁵ Ptolemy used the terms astrolabe and meteoroscope, the first referring to both spherical and planisphaeric instruments, and the second, known only from the commentary of Pappus to Book V of the *Almagest*, referring to a related spherical instrument.²⁶

22. The evidence for this is a remark by a later Maghribi astronomer al-Thaqafī, recorded by Morley in *Gunther*, I, p. 7, note 12. (For Morley’s “Ḥannash” read “Ḥabash”.)

23. MS Damascus Zāhiriya 9255, copied ca. 1500 AD. On al-Sijzī see the article in *DSB* by Y. Dold-Samplonius.

24. See *Samsō* 4, p. 2.

25. See for example, *North*.

26. See *Rome and Neugebauer*, II, p. 941.

Notes added in proof

1. The Aya Sofia manuscript of the treatise in 80 chapters mentioned in note 21 is in fact anonymous. However, another copy of what appears to be the same work, now arranged in 79 chapters and attributed to al-Zarqāllu, has come to light in MS Istanbul Nurosmāniye 2926,6 (fols. 118r-150r, late copy in two different hands).

2. Prof. Franz Rosenthal of Yale University kindly suggested to me various minor corrections to my readings of difficult passages and I have incorporated these into the text of the article. In particular Prof. Rosenthal noted that in the extract from al-Baklamshī presented on p. 248 we should perhaps read *al-aṣṭurlāb al-mughnī... al-mustanbaḥ min al-zarqāliya wa-l-shakkāziya*, which would mean “the universal astrolabe... derived from the *zarqāliya* and the *shakkāziya* (plates)”. This not only makes better sense but also accords with the fact that one of al-Baklamshī’s predecessors in Syria in the fourteenth century had compiled a treatise on a universal instrument which he labelled *al-aṣṭurlāb al-mughnī*. A translation of this treatise is contained in my forthcoming monograph on the instruments of Ibn al-Sarrāj (see note 20 above), which is to be published by the Benaki Museum.

Bibliography and Bibliographical Abbreviations

- Brockelmann: C. Brockelmann, *Geschichte der arabischen Litteratur*, 2 vols., 2nd ed., (Leiden: E. J. Brill, 1943-49), and Supplementbände, 3 vols., (Leiden: E. J. Brill, 1937-42).
- Dozy: R. Dozy, *Supplément aux Dictionnaires Arabes*, 2nd ed., 2 vols., (Leiden: E. J. Brill, and Paris: Maisonneuve Frères, 1927).
- DSB: *Dictionary of Scientific Biography*, 15 vols., (New York: Charles Scribner's Sons, 1970-1978).
- EI₁: *Encyclopaedia of Islam*, 1st, ed., 4 vols., (Leiden: E. J. Brill, 1913-1934).
- EI₂: *Encyclopaedia of Islam*, 2nd ed, 4 vols. to date, (Leiden: E. J. Brill, 1960 to present).
- Gunther: R. T. Gunther, *The Astrolabes of the World*, 2 vols., (Oxford: University Press, 1932).
- Hartner: W. Hartner, Article "Asfurlāb" in EI₂, reprinted in *idem.*, *Oriens-Occidens* (Hildesheim: Georg Olms, 1968), pp. 312-318.
- King 1: D. A. King, "An Analog Computer for Solving Problems of Spherical Astronomy: the Shakkā-ziya Quadrant of Jamāl al-Dīn al-Māridīnī", *Archives Internationales d'Histoire des Sciences*, 24 (1974), 219-242.
- King 2: D. A. King, "The Astronomical Instruments of Ibn al-Sarrāj: a Brief Survey", to appear in the *Proceedings of the Second International Symposium for the History of Arabic Science* (Aleppo, 1979).
- Krause: M. Krause, "Stambuler Handschriften islamischer Mathematiker", *Quellen und Studien zur Geschichte der Mathematik, Astronomie, und Physik*, Abt. B, 3:4 (1936), pp. 437-532.
- Libros del Saber: D. Manuel Rico y Sinobas, ed., *Libros del Saber de Astronomia del Rey D. Alfonso X de Castilla*, 5 vols., (Madrid, 1873).
- Maddison-Turner: F. Maddison and A. Turner, *Catalogue of an Exhibition "Science and Technology in Islam" held at the Science Museum, London, April-August 1976, in association with the Festival of Islam* (unpublished).
- Michel: H. Michel, *Traité de l'Astrolabe* (Paris: Gauthiers-Villars, 1947).
- Millás 1: J. Millás Vallicrosa, "Estudios sobre Azarquiel: El Tratado de la Azafea", *Archeion*, 14 (1932), 393-419.
- Millás 2: J. Millás Vallicrosa, *Estudios sobre Azarquiel*, (Madrid-Granada: Instituto Miguel Asin, Escuelas de Estudios Arabes de Madrid y Granada, 1943-50).
- Millás 3: J. Millás Vallicrosa, *Don Profeít Tibbon: Tractat de l'Assafea d'Azarquiel*, Biblioteca Hebraico-Catalana, vol. IV, (Barcelona, 1933).
- Millás 4: J. Millás Vallicrosa, "Un Ejemplar de Azafea Arabe de Azarquiel", *Al-Andalus*, 9 (1944), 111-119.
- Neugebauer: O. Neugebauer, *A History of Ancient Mathematical Astronomy*, 3 Pts., (Berlin-Heidelberg-New York: Springer Verlag, 1975).
- North: J. D. North, "Werner, Apain, Blagrove, and the Meteoroscope", *British Journal of the History of Science*, ca. 1965 (?), 57-65.
- Poulle: E. Poulle, "Un instrument astronomique dans l'occident latin, la "saphea", in *A Giuseppe Ermini* (Spoleto: Centro Italiano di Studi sull'Alto Medioevo, 1970), pp. 491-570".

- Renaud: H. P. J. Renaud, *Les Manuscrits Arabes de l'Escorial*, Tome II, Fasc. 3: *Sciences Exactes et Sciences Occultes*, (Paris: Paul Geuthner, 1941).
- Rome: A. Rome, "L'Astrolabe et le Météoroscope d'après le commentaire de Pappus sur le 5^e livre de l'Almageste", *Annales de la Société Scientifique de Bruxelles*, 47 (1927), 1-26.
- Šā'id al-Andalusī: Abu'l-Qāsim Šā'id ibn Aḥmad ibn Šā'id al-Andalusī, *Kitāb Ṭabaqāt al-Umam*, ed. L. Cheikho, (Beirut: Catholic Press of the Jesuit Fathers, 1913); translated as *Livre des Catégories des Nations* by R. Blachère, (Paris: Larose Editeurs, 1935).
- Samsó 1: J. Samsó Moya, "Nota acerca de Cinco Manuscritos sobre Astrolabio", *Al-Andalus*, 31 (1966), 385-392.
- Samsó 2: J. Samsó Moya, "Una Hypotesis sobre Calculo por Aproximacion con el Cuadrante Shakkāzī", *Al-Andalus*, 36 (1971), 117-126.
- Samsó 3: J. Samsó Moya, "A propos de quelques manuscrits astronomiques des bibliothèques de Tunis: Contribution à une étude de l'astrolabe dans l'Espagne Musulmane", *II Coloquio Hispano Tunecino*, n.d., pp. 171-190.
- Samsó 4: J. Samsó Moya, "Astronomica Isidoriana", *Faventia* (Barcelona), 1 (1979), 1-8.
- Samsó-Catalá: J. Samsó Moya and M. A. Catalá, "Un Instrumento Astronomica de Raigambre Zarqālī: el Cuadrante Shakkāzī de Ibn Ṭibugā", *Memorias de la Real Academia de Buenas Letras de Barcelona*, XIII:I (1971), 5-31.
- Sédillot-fils: L. A. Sédillot, "Mémoire sur les Instruments Astronomiques des Arabes", *Mémoires de l'Académie Royale des Inscriptions et Belles-lettres de l'Institut de France*, 1 (1844), 1-229.
- Suter: H. Suter, "Die Mathematiker und Astronomen der Araber und ihre Werke", *Abhandlungen zur Geschichte der mathematischen Wissenschaften*, 10 (1900).
- Vera: F. Vera, *La Matemática de los Musulmanes Espanoles* (Buenos Aires: Editorial Nova, 1947).
- Voorhoeve: P. Voorhoeve, *Handlist of Arabic Manuscripts in the Library of the University of Leiden...* (Leiden: University Press, 1957).