Biographical Encyclopedia of Astronomers

Zarqālī: Abū Ishaq Ibrāhīm ibn Yahyā al-Naqqash al-Tujībī al-Zarqālī

Died in Córdova, (Spain), 15 October 1100

According to his biographer Ishaq Israeli, Zarqali was a renowned instrument maker in Toledo, where he taught himself astronomy. He worked for Sha'id al-Andalusi and was a leading figure among Sa'id's group of astronomers. An anonymous 14th-century Egyptian source (*Kanz al-yawāqīt*, Leiden University Library, MS 468) quotes a passage from Sa'id's lost work entitled *Tabaqat al-hukamā'*, which states that Zarqali constructed an astronomical instrument, called *al-zarqāla*, for al-Mamūn (1043–1075), the ruler of Toledo, in 1048/1049. It also states that Zarqālī wrote a treatise of 100 chapters on its use. Zarqali left Toledo between 1081, the beginning of al-Qadir's reign, and 1085, the year of Alfonso VI's conquest of the city. He settled in Córdova, where he was protected by al-Mu'tamid ibn 'Abbād (1069-1091), ruler of Seville.

There are many variations of the name of Zarqālī, known as Azarquiel in Latin. According to the *Tabaqat al-umam* of Ṣa id al-Andalusi, he was known as *walad al-Zarqiyal*, from which came the Hispanicized form *Azarquiel*. The 13th-century biographer al-Qifţi maintains the expression *walad al-Zarqiyal* in his *Akhbar al-'ulama" bi-akhbar al-hukama*. Other readings quoted in Andalusian sources are al-Zarqalluh, al-Zarqal, or Ibn Zarqal; readings such as al-Zarqala and al-Zarqali (sometimes al-Zarqānī) seem to be classicized Eastern forms

In his *Jāmi 'al-mabādi wa-'l-ghāyāt fi 'ilm al-miqāt*, an encyclopedic work on astronomy, Abū al-Hasan Ali al-Marrākushi (13th century) states that Zarqali was making observations in Toledo in 1061. This testimony is confirmed by Ibn al-Ha'im al-Ishbīlī (flourished: 1204/1205) in his *al-Zij al-kāmil fi al-ta ālīm*, who attributes to Zarqali 25 years of solar observations and 37 years of observations of the Moon. Al-Qifţi says that his observations were used by Ibn al-Kammād

One can generally classify the contents of Zarqali's work under four main categories: astronomical theory, astronomical tables, magic, and astronomical instruments.

The following four works by Zarqali deal with astronomical theory: (1) There is a treatise on the motion of the fixed stars, written circa 1084/1085 and extant in Hebrew translation. It contains a study of three different trepidation models, in the third of which variable precession becomes independent of the oscillation of the obliquity of the ecliptic. (2) There is a lost work summarizing 25 years of solar observations, probably written *circa* 1075–1080. Its contents are known through secondary sources, both Arabic and Latin. The title was either *Fi sanat al-shams* (On the solar year) or *al-Risala al-jamí a fi al-shams* (A comprehensive epistle on the Sun). In this work, Zarqālī established that the solar apogee had its own motion (of about 1° in 279 Julian years) and devised a solar model with variable eccentricity that became influential both in the Maghrib and in Latin Europe until the time of Nicolaus Copernicus. (3) There is an indirect reference to a theoretical work entitled *Maqāla fi ibtāl al-tariq allati salaka-hā Batlīmūs fi istikhrāj al-bu'd al-abad li- Utarid* (On the invalidity of Ptolemy's method to obtain

the apogee of Mercury) mentioned by Ibn Bājja. (4) There is a reference in Ibn al-Ha'im's work to Zarqālī's lost writing (*bi-khatt yadi-hi*, in his own hand) describing a correction to the Ptolemaic lunar model. Ibn al-Ha'im understands this correction as a result of the displacement of the center of the lunar mean motion in longitude to a point on a straight line linking the Earth's center with the solar apogee, at a distance of 24 arcminutes. This model met with some success, for we find the same correction in later Andalusian (Ibn al-Kammad) and Maghribi (Ibn Ishaq, Ibn al-Banna) *zījes*, although restricted to the calculation of eclipses and the New Moon. It also appears in the Spanish canons of the first version of the *Alfonsine Tables* and in a Provençal version of the tables of eclipses of Gersonides, although in these tables the amount is given as 29' (either a copying error or a new estimation).

There are two works by Zarqali dealing with astronomical tables: (1) The *Almanac* is preserved in Arabic, Latin, and in an Alfonsine translation. It is based on a Greek work calculated by a certain Awmātiyūs in the 3rd or 4th century, although the solar tables seem to be the result of the Toledan observations. Its purpose is to simplify the computation of planetary longitudes using Babylonian planetary cycles (goal years). (2) The *Toledan Tables* are known through a Latin translation They seem to be the result of an adaptation of the best available astronomical material (i.e., Khwarizmi and Battānī) to the coordinates of Toledo, made by a team led by Sa'id, in which Zarqālī seems to have been a prominent member. The mean-motion tables are original and are the result of observations. Sa'id does not mention these tables, although they had been completed before the writing of the *Tabaqat* in 1068.

The only known magical work by Zarqālī is entitled *Risāla fi Harakat al-kawakib al-sayyāra wa-tadbiri-hi* (On the motions and influences of planets), which is a treatise on talismanic magic using magic squares to make talismans. It is preserved in two Arabic manuscripts, which contain two different versions of the text. There is also a third one summarized in a Latin translation

Finally, Zarqali has several works on astronomical instruments: (1) There is a treatise on the construction of the armillary sphere, which is preserved in an Alfonsine-Castilian translation.

The original Arabic has not survived. (2) There are two treatises on the construction (circa 1080/1081) and use (*circa* 1081/1082) of the equatorium, dedicated to al-Mu'tamid. Zarqali's equatorium differs from the earlier Andalusian model designed by Ibn al-Samh (circa 1025/1026) in that it is an independent instrument that represents all the planetary deferents and related circles on both sides of a single plate, while a second plate bears all the epicycles. Mercury's deferent is represented as an ellipse (3) Marrākushi attributes to Zarqali a sine quadrant with a movable cursor (majarra), which is a graphic scale of solar declination with solar longitude as the argument. It is similar to the quadrant vetustissimus, although in this quadrant the argument used is the date of the Julian year. (4) There are two treatises on two variants of the same astronomical universal instrument (*al-ṣafiha al-mushtaraka li-jami al-'urūd*): a 100-chapter treatise on the use of the *safiha* (plate), called the *zarqaliyya*, and another treatise of 60 chapters on the use of the *safiha shakkāziyya*. In both instruments, the stereographic equatorial projection of the standard astrolabe is replaced by a stereographic meridian projection onto the plane of the solstitial color. In fact, it is a dual projection corresponding to each of the Celestial Hemispheres, one of which had its viewpoint at the

beginning of Aries and the other at the beginning of Libra. The final result was obtained by superimposing the projection from Aries (turning it) onto the projection from Libra. The two variants of the *safiha* differ slightly. The *zarqāliyya* has, on its face, a double grid of equatorial and ecliptical coordinates and a ruler horizon representing the horizontal ones. On its back, in addition to the features proper to the astrolabe, it shows an orthographic meridian projection of the sphere, a trigonometric quadrant, and a small circle (named "of the Moon") used to compute the geocentric distance of the Moon. The *shakkāziyya* is a simplification of the *zarqāliyya*, as Marrākushi states in his *Jāmí*. On its front, it bears a single grid of equatorial coordinates and a grid of ecliptical coordinates reduced to the ecliptic line and the circles of longitude marking the beginning of the zodiacal signs. The back of this kind of *safiha* is the same as the back of the astrolabe. There is an Alfonsine translation of the treatise on the *zarqaliyya*, as well as several translations into Latin and Hebrew of the treatise on the *shakkaziyya*.

Roser Puig

Alternate name

Azarquiel

Selected References

Al-Marrākushi, Abū al-Hasan Ali (1984). *Jāmi 'al-mabadi' wa-'l-ghāyāt fi ilm al-mīgāt.* Facsimile edition. Frankfurt am Main. Partially translated in J. J. Sédillot, Traité des instruments astronomiques des arabes, Paris, 1834-1835. (Reprint, Frankfurt, 1984); 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 (1894): 1-229. (Reprint, Frankfurt, 1989.)

Al-Qifţi, Jamal al-Din *Akhbar al-Sulama' bi-akhbar al-Hukama'*. Beirut, n.d.

Boutelle, Marion (1967). "The Almanac of Azarquiel." *Centaurus* 12: 12-20.

Comes, Mercè (1991). *Ecuatorios andalusies: Ibn al-Samb, al-Zarqälluh y Abü-I-Salt.* Barcelona.

Goldstein, Bernard R. (1964). "On the Theory of Trepidation according to Thabit b. Qurra and al-Zarqallu and Its Implications for Homocentric Planetary Theory." *Centaurus* 10: 232-247

Ibn al-Abbār (1920). *Al-Takmila li-kitāb al-Şila*, edited by A. Bel and M. Ben Cheneb. Algiers.

Israeli, R. Isaac (1946–1948). *Liber Jesod olam seu Fundamentum mundi*, edited by B. Goldberg and L. Rosenkranz, with commentary by D. Cassel. Berlin.

King, David A. (1986). *A Survey of the Scientific Manuscripts in the Egyptian National Library.* Winona Lake, Indiana: Eisenbrauns.

—— (1997). "Shakkaziyya." In *Encyclopaedia of Islam*. 2nd ed. Vol. 9, pp. 251–253. Leiden: E. J. Brill

Mercier, Raymond (1987). "Astronomical Tables in the Twelfth Century." In *Adelard of Bath: An English Scientist and Arabist of the Early Twelfth Century*, edited by Charles Burnett, pp. 87–118. London: Warburg Institute. (See pp. 104–112.)

Millás Vallicrosa, José María (1932). "La introducción del cuadrante con cursor en Europa." *Isis* 17: 218–258. (Reprinted in Millás Vallicrosa, Estudios sobre historia de la ciencia española. Barcelona, 1949.)

—— (1943–1950). *Estudios sobre Azarquiel*. Madrid–Granada

Puig, Roser (1985). "Concerning the safiḳa shakkāziyya." *Zeitschrift für Geschichte der Arabisch-islamischen Wissenschaften* 2: 123-139.

—— (1987). *Los tratados de construcción y uso de la azafea de Azarquiel*. Madrid.

—— (2000). "The Theory of the Moon in the Al-Zij al-Kamil fi-l-Ta'alim of Ibn al-Ha'im (ca. 1205)." *Suhayl* 1:71-99.

—— (1986). *Al-Šakkāziyya: Ibn al-Naqqāš al-Zarqalluh. Edición, traducción y estudio*. Barcelona

Rico y Sinobas, Manuel (1863-1867). *Libros del saber de astronomía del rey D. Alfonso X de Castilla, copilados, anotados y comentados por Don Manuel Rico y Sinobas*. 5 Vols. Madrid.

Richter-Bernburg, Lutz (1987). "Ṣā'id, the Toledan Tables, and Andalusi Sci-ence." In *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*, edited by David A. King and George Saliba, pp. 373-401. Annals of the New York Academy of Sciences. Vol. 500. New York: New York Academy of Sciences

Ṣa'id al-Andalusi (1985). *Kitāb Tabaqat al-umam*, edited by Hayat Bü Alwan. Beirut. (French translation with notes by Régis Blachère as Livre des caté-gories des nations. Paris: Larose, 1935.)

Samsó, Julio (1992). *Las ciencias de los antiguos en al-Andalus*. Madrid: Mapfre.

—— (1994). "Trepidation in al-Andalus in the 11th Century." In *Islamic Astronomy and Medieval Spain*, VIII. Aldershot: Variorum.

—— (1994). "Sobre el modelo de Azarquiel para determinar la oblicuidad de la eclíptica." In *Islamic Astronomy and Medieval Spain*, IX. Aldershot: Variorum.

—— (1994). "Ibn al-Banna, Ibn Ishaq and Ibn al-Zarqalluh's Solar Theory." In *Islamic Astronomy and Medieval Spain,* X. Aldershot: Variorum

—— (2002). "Al-Zarḳāli." In *Encyclopaedia of Islam*. 2nd ed. Vol. 11, pp. 461- 462. Leiden: E. J. Brill.

Samsó, Julio and Honorino Mielgo (1994). "Ibn al-Zarqalluh on Mercury." *Journal for the History of Astronomy* 25: 289-296.

Sesiano, Jacques (1996). *Un traité médiéval sur les carrés magiques: De l'arrangement harmonieux des nombres*. Lausanne: Presses polytechniques et universitaires romandes.

Toomer, G. J. (1968). "A Survey of the Toledan Tables." *Osiris* 15:5-174

(1969). "The Solar Theory of az-Zarqal: A History of Errors." *Centaurus* 14:306-336.

(1987). "The Solar Theory of az-Zarqal: An Epilogue." In *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, edited by David A. King and George Saliba, pp. 513-519. Annals of the New York Academy of Sciences. Vol. 500. New York: New York Academy of Sciences