Biographical Encyclopedia of Astronomers

Kāshī: Ghiyāth (al-Milla wa-) al-Din Jamshid ibn Mas'ūd ibn Mahmūd al-Kāshī [al-Kāshānī]

Died Samarkand, (Uzbekistan), possibly 22 June 1429

Kāshī was one of the most accomplished and prolific scientists at the Samarkand Observatory, which itself was one of the preeminent scientific institutions of the 15th century. Kāshī was born in Kāshān in northern Iran and had long worked on astronomical problems before finding a patron. Despite being a physician (as he mentions at the end of his *Risāla dar sharh-i ālāt-i rasd*), he tells us in his *Zīj* that he had lived in poverty in various cities of central Iran, mostly in his hometown Kashi first found patronage in Herat at the court of Shah Rukh, son of Timur and father of Ulugh Beg. On June 2, 1406, Kashi returned to Kashan, where he witnessed a lunar eclipse, as he did again in 1407 and in 1416, the latter year he presented his book, the *Nuzha*. Presumably between 1417 and 1419, Kashi was invited to Samarqand by Ulugh Beg. It was most likely in 1420 that he made the long journey north to Samarqand, where he joined the scientific circle at the prince's residence. Under Ulugh Beg's sponsorship, Kashi finally obtained a secure and honorable position, becoming the prince's closest collaborator and consultant. In the introduction to Ulugh Beg's *Zij* (astronomical handbook with tables), Kāshī is singled out for praise. When the observatory was founded in 1420, Kāshī participated in its construction, organization, and provisioning, as well as in the preparation of Ulugh Beg's *Zij*. During this time, he traveled with the royal retinue to Bukhārā, as he mentions in letters to his father. Kāshī, the most prominent of the scholars associated with Ulugh Beg's learned staff, spent the rest of his life as a distinguished scientist in Samarkand, where he died, leaving incomplete the observations required for Ulugh Beg's *Zij*.

Although Kashi wrote a number of important mathematical treatises, we will here be concerned only with his astronomical works. It is worth mentioning, though, that he was a remarkable computational mathematician whose calculations of sin 1° (correct to 18 decimal places) and π (correct to 16 decimal places) were to remain unsurpassed for some time

Probably while living in Kashan, Kashi wrote two minor astronomical treatises. The first, entitled either the *Sullam al-sama'* or the *Risala kamaliyya*, dealt with the sizes and distances of the celestial bodies. Completed on 1 March 1407, it is dedicated to a vizier named Kamal al-Din Mahmud and is preserved in several copies. The second is the *Mukhtasar dar 'ilm-i hayat*, a compendium on astronomy written in 1410/1411 for a certain Sultan Iskandar, probably a nephew of Shah Rukh and a cousin of Ulugh Beg; it is preserved in two Persian manuscripts in London and Yazd

In 1413/1414, Kashi completed his *Zij-i Khāqānī*, which was dedicated either to Shah Rukh, for Kashi was staying in Herat at this time, or to Ulugh Beg, for he says in the *Zij-i Khāqānī* that he would not have been able to finish his work without the prince's support. Kashi's *Zij*, preserved in several Persian copies, is organized into six treatises and begins with an introduction in which Kashi pays respect to Nasir al-Din al-Tūsī, but expresses his

dissatisfaction with much of Tūsi's *İlkhānī Zij*, which Kashi proposes to correct. The first treatise of Kashi's *Zij* contains the chronological section with a description of the common calendars in use; The second section is the mathematical section with a presentation of the standard trigonometric and astronomical functions; the third and fourth sections cover spherical astronomy with procedures and solutions to problems in spherical astronomy, including tables; the fifth section contains different solutions for determining the ascendant; and the sixth section presents astrological material. Each treatise includes an introduction with a glossary of technical terms, and two chapters with solutions, computations, and proofs. The tables computed by Kāshi use pure sexagesimals; the sine tables give four sexagesimal places for each minute of arc. Kāshī also mentions some observational instruments such as the mural quadrant and the revolving parallactic ruler, seemingly the "perfect instrument" of Urdi.

In January 1416, presumably in Kāshān, Kāshī composed by order of Sultan Iskandar, possibly the Qara-Qoyunlu king, the *Risala dar sharh-i ālāt-i raşd*, a commentary on observational instruments, preserved in two Persian manuscripts in Leiden and Tehran. Most of the instruments described by Kāshī are mentioned by Ptolemy and/or listed in Urdī, such as the parallactic ruler for measuring zenith distances, an armillary sphere, an equinoctial sphere, and a solstitial armilla Furthermore, he describes the Fakhri sextant, used for measuring the altitude of stars. This instrument, invented by Khujandi around 1000 in Rayy, was also described by Marrākushi and confirmed by Bīrūnī. Kāshī's treatise clearly demonstrates that he had some knowledge of the observatory in Marāgha. His work represents a connecting link between these two great centers of medieval astronomical activity, centers whose influence reached at least as far as Istanbul to the west, and China and India to the east, if not to the earliest European observatories.

In the *Nuzhat al-hadā'iq*, Kashi describes two instruments that he invented: the "plate of heavens" and the "plate of conjunctions." The first version of this text was finished in Kāshān on 10 February 1416, which is preserved in an Arabic manuscript in London The second version was revised in Samarkand in June 1426. It is only known in a lithographic edition of some of Kashi's works, printed in Tehran in 1888/1889. The "plate of heavens" is a planetary equator, a computing instrument to find the true position of a planet, an alternative to lengthy numerical computations by reducing an essentially three-dimensional problem to a succession of two-dimensional operations. Kashi's "plate of heavens" is the only example recovered from the lands of eastern Islam, and moreover, the most compact, which includes a method for determining planetary longitudes as well as latitudes. His "plate of conjunctions" is a simple device for performing linear interpolation, a mechanical application of elementary geometry, for ascertaining the time of day at which expected planetary conjunctions will occur.

Besides these works, Kashi wrote numerous minor astronomical treatises In his *Tarīb al-zīj*, preserved in Leiden and Tashkent, he translated the introduction of Ulugh Beg's *Zij* from Persian into Arabic, a translation completed during Kāshī's lifetime. He also wrote the *Miftah al-asbab fi ilm al-zīj* (The Key of the Causes in the Science of Astronomical Tables), extant in an Arabic manuscript in Mosul; the *Risala dar sakht-i asturlab*, on the construction of the astrolabe, extant in a Persian manuscript in Meshed; and the *Risala fi ma'rifat samt al-qibla min da'ira hindiyya ma'rufa*, on the determination of the *qibla* by means of the "Indian Circle,"

extant in an Arabic manuscript in Meshed. The *Zij al-tashīlāt*, which Kāshī mentions in his *Miftah al-hisab*, appears not to be extant. The alleged *al-Risāla al-iqlīlāmina* (mentioned by Kennedy in Planetary Equatorium, p. 7) is a misattribution based on a misreading.

Though they are not astronomical treatises, two letters that Kāshī sent from Samarkand to his father in Kāshān are nonetheless very informative. The first of them, preserved in Tehran, was written about 1423. Because Kāshī believed it was lost, sometime after the first letter he composed a second, which contains descriptions similar to that in the first, but also includes some new information. It is preserved in three Persian manuscripts in Tehran. Both letters describe Ulugh Beg as a generous and learned man. Kāshī praises his erudition and mathematical capacity, and gives a picture of the prince as a scientist among those brought together and patronized by him The observatory was founded as Kāshī had suggested, quite similar to the earlier observatory in Maragha. Its building was aligned with the meridian on the top of a rock, into which parts of the Fakhri sextant were carved, with a flat roof for the placement of additional instruments. Kāshī mentions several instruments constructed for the observatory, some of which are also listed in his commentary on observational instruments. Furthermore, Kāshī describes a sundial on an inclined wall, a device for determining the time of the afternoon prayer, and a *zarqāla*, a universal astrolabe invented by Zarqālī in 11th-century Andalusia. Kāshī had a very positive self-image and told his father that he knew how to solve problems others could not. On his father's advice, he was completely engaged in working at the observatory, but this left him little time for anything else.

Kāshī was unaffected by the newer planetary theories of the "School of Maragha," but his improvement and correction of *the Ilkhani Zīj* of Nasir al-Din al-Tūsi is of remarkable accuracy. In the letters to his father, Kāshī gives a unique glimpse into the court of Ulugh Beg and the observatory at Samarkand, as well as into the work and life of a medieval astronomer.

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