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Kāshī: Ghiyāth (al-Milla wa-) al-Dīn Jamshīd ibn Masʿūd ibn Maḥmūd al-Kāshī [al-Kāshānī]

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Died **Samarqand, (Uzbekistan), possibly 22 June 1429**

Kāshī was one of the most accomplished and prolific scientists at the Samarqand 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 sharḥ-i ālāt-i raṣd*), he tells us in his *Zīj* that he had lived in poverty in various cities of central Iran, mostly in his hometown. Kāshī first found patronage in Herat at the court of Shāh Rukh, son of Tīmūr and father of **Ulugh Beg**. On 2 June 1406 Kāshī was back in Kāshān, where he witnessed an eclipse of the Moon, as he did also in 1407 as well as in 1416 at which time he presented his book the *Nuzha*. Presumably between 1417 and 1419 Kāshī 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 residence of the prince. Under Ulugh Beg's sponsorship, Kāshī finally obtained a secure and honorable position, becoming the prince's closest collaborator and consultant. In the introduction of Ulugh Beg's *Zīj* (astronomical handbook with tables), Kāshī is singled out for praise. When the observatory was founded in 1420, Kāshī took part in its construction, organization, and provision, as well as in the preparation of Ulugh Beg's *Zīj*. During this time, he traveled with the royal retinue to Bukhārā, as he mentions in the 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 Samarqand, where he died, leaving incomplete the observations required for Ulugh Beg's *Zīj*.

Although Kāshī 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 Kāshān, Kāshī wrote two minor astronomical treatises. The first, entitled either the *Sullam al-samā'* or the *Risāla kamāliyya*, dealt with the sizes and distances of the celestial bodies. Completed on 1 March 1407, it is dedicated to a vizier named Kamāl al-Dīn Maḥmūd and is preserved in several copies. The second is the *Mukhtaṣar dar 'ilm-i hay'at*, a compendium on astronomy written in 1410/1411 for a certain Sultan Iskandar, probably a nephew of Shāh Rukh and a cousin of Ulugh Beg; it is preserved in two Persian manuscripts in London and Yazd.

In 1413/1414 Kāshī completed his *Zīj-i Khāqānī*, which was either dedicated to Shāh Rukh, for Kāshī was staying in Herat in this time, or to Ulugh Beg, for he says in the *Zīj-i Khāqānī* that he would not

have been able to finish his work without the support of the prince. Kāshī's *Zīj*, preserved in several Persian copies, is organized in six treatises and starts with an introduction in which Kāshī pays respect to **Naṣīr al-Dīn al-Ṭūsī**, but expresses his dissatisfaction with much of Ṭūsī's *Īlkhānī Zīj*, which Kāshī proposes to correct. The first treatise of Kāshī's *Zīj* contains the chronological section with a description of the common calendars in use; the second the mathematical section with a presentation of the standard trigonometric and astronomical functions; the third and fourth the spherical astronomy section with procedures and solutions of problems in spherical astronomy including tables; the fifth different solutions for the determination of the ascendant; and the sixth 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 Kāshī 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 **ʿUrḍī**.

In January 1416, presumably in Kāshān, Kāshī composed by order of Sultan Iskandar, possibly the Qarā-Qoyunlu king, the *Risāla dar sharḥ-i ālāt-i raṣd*, 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 ʿUrḍī, such as the parallactic ruler for the measurement of zenith distances, an armillary sphere as well as an equinoctial, and a solstitial armilla. Further, he describes the Fakhrī sextant, used for the measurement of the altitude of stars. This instrument, invented by **Khujandī** about 1000 in Rayy, was also described by **Marrākushī** and confirmed by **Bīrūnī**. Kāshī's treatise demonstrates clearly that he had some knowledge on 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-ḥadāʾiq* Kāshī 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 Samarqand in June 1426. It is only known in a lithographic edition of some of Kāshī's works, printed in Tehran 1888/1889. The "plate of heavens" is a planetary equatorium, a computing instrument to find the true position of a planet, an alternative to lengthy numerical computations by means of reducing an essentially three-dimensional problem to a succession of two-dimensional operations. Kāshī'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 the determination of 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, Kāshī wrote numerous minor astronomical treatises. In his *Taʿrīb al-zīj*, preserved in Leiden and Tashkent, he translated the introduction of Ulugh Beg's *Zīj* from Persian into Arabic, the translation being completed during Kāshī's lifetime. Further, he wrote the *Miftāḥ al-asbāb fī ʿilm al-zīj* (The key of the causes in the science of astronomical tables), extant in an Arabic manuscript in Mosul; the *Risāla dar sakht-i asṭurlāb*, on the construction of the astrolabe, extant in a Persian manuscript in Meshed; and the *Risāla fī maʿrifat samt al-qibla min dāʾira hindiyya maʿrūfa*, on the determination of the *qibla* by means of the "Indian circle," extant in an Arabic manuscript in Meshed. The *Zīj al-tashīlāt*, which Kāshī mentions in his *Miftāḥ al-ḥisāb*, seems 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 Samarqand 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 Marāgha. Its building was aligned in the meridian on the top of a rock, in which parts of the Fakhrī sextant are carved, with a flat roof for the placing of further instruments. Kāshī mentions several instruments constructed for the observatory, some of them listed in his commentary on observational instruments as well. Further, Kāshī describes a sundial at an inclined wall, a device for the determination of the afternoon prayer, and a *zarqāla*, a universal astrolabe invented by **Zarqālī** in 11th-century Andalusia. Kāshī had a very positive image of himself and told his father that he knew how to solve problems others could not. On his father's advise, he was completely engaged in working at the observatory, but this left him little time to do anything else.

Kāshī was unaffected by the newer planetary theories of the "School of Marāgha," but his improvement and correction of the *Īlkhānī Zīj* of Naṣīr al-Dīn al-Ṭūsī 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 Samarqand, as well as into the work and life of a medieval astronomer.

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