

Biographical Encyclopedia of Astronomers

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Ulugh Beg: Muhammad Taraghāy ibn Shahrukh ibn Timūr

Born Sulṭāniyya, (Iran), 22 March 1394

Died near Samarkand, (Uzbekistan), 27 October 1449

Ulugh Beg (Turkish for "great prince") was governor of Transoxiana and Turkestan and, during the last two years of his life, Timurid Sultan. However, he is mostly remembered as a patron of mathematics and astronomy. In Samarkand, he founded a school and the famous astronomical observatory, where the most extensive observations of planets and fixed stars at any Islamic observatory were made. Ulugh Beg is associated with a Persian astronomical handbook (*zīj*) that stands out for the accuracy with which its tables were computed

Ulugh Beg was the firstborn son of Shahrukh (youngest son of the infamous conqueror Timur or Tamerlane) and his first wife, Gawharshad. He was raised at the court of his grandfather and, at the age of 10, was married to his cousin Agha Biki, whose mother was a direct descendant of Genghis Khan. Thus, Ulugh Beg could use the epithet *Gūrgan*, "royal son-in-law," which had originally been used for Genghis's son-in-law

In the years after Timur's death in 1405, Ulugh Beg became governor of Turkestan and Transoxiana, the most important cities of which were the cultural centers of Samarkand and Bukhara. Although not completely divorced from affairs of state, he is better known for his interest in religion, architecture, arts, and sciences, which were fostered by the Mongols as well as by the Timurids. Ulugh Beg is said to have spoken Arabic, Persian, Turkish, Mongolian, and some Chinese. He had a thorough knowledge of Arabic syntax and also wrote poetry. Although he honored Turkic-Mongolian customs, he also knew the Quran by heart, including commentaries and citations. Ulugh Beg was also a passionate hunter.

By 1411, Ulugh Beg had developed a lively interest in mathematics and astronomy, which may have been aroused by a visit in his childhood to the remnants of the Maragha Observatory that had been directed by Tūsī. In 1417, he founded a *madrasa* (religious school or college) in Samarkand that can still be seen on Registan Square. At this institution, unlike other *madrasas*, mathematics and astronomy were among the most important subjects taught. The most prominent teacher was Qādīzāde al-Rūmī, who was joined some-what later by Kāshī

Two extant letters from Kāshī to his father in Kashan make it clear that Ulugh Beg was personally involved in the appointment of scholars and that he was frequently present and actively participated in seminars, where he displayed a good knowledge of mathematical and astronomical topics. Kāshī relates how Ulugh Beg performed complicated astronomical calculations while riding on horseback. Anecdotes from other sources show that Ulugh Beg, like many other Muslim rulers, believed in astrology and fortune-telling. He appears as a person who very much respected the scholars he appointed, and whose main objective was to attain scientific truth

In 1420, Ulugh Beg founded his famous astronomical observatory on a rocky hill outside the city of Samarkand. Its circular main building, beautifully decorated with glazed tiles and marble slabs, had a diameter of about 46 m and three stories reaching a height of approximately 30 m above ground level. The north-south axis of the main building was occupied by a huge sextant with a radius of 40 m (called the Fakhri sextant after that of Khujandi). On the scale of this instrument, which partially lay in an underground slit half a meter wide, 70 cm corresponded to 1° of arc, so that the solar position could be read off with a precision of 5".

On the flat roof of the main building, various smaller instruments could be placed, such as an armillary sphere, a parallactic ruler, and a triquetrum. Among other instruments known to have been used in Samarkand are astrolabes, quadrants, and sine and versed sine instruments.

Although Ulugh Beg was the director of the Samarkand Observatory, Kashi was in charge of observations until his death in 1429, after which he was succeeded by Qadizade, who died after 1440. The observational program was completed by Qushji, who had studied in Kirman (southern Iran) before returning to Samarkand. The results of the observations made under Ulugh Beg include the measurement of the ecliptic obliquity as $23^\circ 30'17''$ (the actual value at the time was $23^\circ 30'48''$) and that of the latitude of Samar-qand as $39^\circ 37'33''$ N (modern value: $39^\circ 40'$). Furthermore, most of the planetary eccentricities and epicyclic radii were newly determined, and the longitudes and latitudes of the more than 1,000 stars in Ptolemy's star catalogue were verified and corrected. Precession was found to amount to $51.4''$ per year (corresponding to 1° in little more than 70 years; the actual value is $50.2''$ per year).

The observatory of Ulugh Beg remained in operation for little more than 30 years. It was finally destroyed in the 16th century and completely covered by earth over time. In 1908, archaeologist V. L. Vyatkin recovered the underground part of the Fakhri sextant, consisting of two parallel walls faced with marble and the section of the scale between 80° and 57° of solar altitude. Ulugh Beg's observatory exerted a large influence on the huge masonry instruments built by Jai Singh in five Indian cities (most importantly Jaipur and Delhi) in the 18th century, more than 100 years after the invention of the telescope.

The main work with which Ulugh Beg is associated is an astronomical handbook with tables in Persian, variously called *Zij-i Ulugh Beg*, *Zij-i Jadīd-i Sultāni*, or *Zij-i Gūrgānī*. In the introduction, Ulugh Beg acknowledges the collaboration of Qādīzāde, Kāshi, and Qūshji, who were undoubtedly responsible for the underlying observations as well as the computation of the tables. The *Zij* is in many respects a standard Ptolemaic work without any adjustments to the planetary models. It consists of four chapters dealing with chronology, trigonometry and spherical astronomy, planetary positions, and astrology, respectively. The instructions for the use of the tables, which were edited and translated into French by L. Sédillot in the middle of the 19th century, are clear but very brief and do not even include examples of the various calculations.

Thus, the most significant part of Ulugh Beg's *Zij* lies in the observations and computations underlying the tables. Most impressively, the sine table, covering 18 pages in the manuscript copies, displays the sine to five sexagesimal places (corresponding to nine decimals) for every

arc minute from 0° to 87° and to six sexagesimal places (11 decimals) between 87° and 90° . All independently calculated values for multiples of 5' are correct to the given precision, whereas the intermediate values, calculated by means of quadratic interpolation, contain incidental errors of at most two units. Most of the planetary tables in the *Zij* were also calculated to a higher precision than before. New types of tables were added that simplified the calculation of planetary positions. Ulugh Beg's star catalog for the year 1437 represents the only large-scale observations of star coordinates made in the Islamic realm during the medieval period. (Most other catalogs simply adjusted Ptolemy's ecliptic coordinates for precession or were limited to a relatively small number of stars.)

Ulugh Beg's *Zij* was highly influential and continued to be used in the Islamic world until the 19th century. It was soon translated into Arabic by Yahya ibn 'Alī al-Rifa'i and into Turkish by 'Abd al-Rahman 'Uthman. Reworkings for various localities were made in Persian, Arabic, and Hebrew by scholars such as 'Imad al-Din ibn Jamāl al-Bukhārī (Bukhara), Ibn Abi al-Fath al-Ṣūfī (Cairo), Mullā Chānd ibn Baha' al-Din and Farid al-Din al-Dihlawi (both Delhi), and Sanjaq Dar and Husayn Qus'a (Tunis). Commentaries to the *Zij* were written by Qūshji, Miram Chelebī, Birjandī, and many others. Hundreds of manuscript copies of the Persian original of Ulugh Beg's *Zij* are extant in libraries all over the world. Already in 17th-century England, various parts of the *Zij* were published in edition and/or translation.

Little is known about other works of Ulugh Beg. A marginal note by him in the India Office manuscript of Kashis *Khaqānī Zij* presents a clever improvement of a spherical astronomical calculation. A *Risāla fi istikhraj jayb daraja wāhida* (Treatise on the extraction of the sine of 1°) has been attributed to Ulugh Beg on the basis of a citation in Birjandi, although most manuscripts of this work mention Qādīzāde as the author. Aligarh Muslim University Library lists a treatise *Risāla-yi Ulugh Beg* that is yet to be inspected. Finally, an astrolabe now preserved in Copenhagen and made in 1426/1427 by Muhammad ibn Ja'far al-Kirmānī, who is known to have worked at the observatory in Samarkand, was originally dedicated to Ulugh Beg.

In 1447, Ulugh Beg succeeded his father Shahrūkh as sultan of the Timurid empire. However, he was killed on the orders of his son 'Abd al-Latif. An investigation of Timur's mausoleum by Soviet scholars in the 1940s showed that Ulugh Beg was buried as a martyr in accordance with *Sharia* (Islamic law), i.e., fully clothed in a sarcophagus.

Benno van Dalen

Alternate name

Gürgān

Selected References

Bagheri, Mohammad (1997). "A Newly Found Letter of Al-Kashi on Scientific Life in Samarkand." *Historia Mathematica* 24: 241-256.

Barthold, V. V. (1958). *Four Studies on the History of Central Asia*. Vol. 2, *Ulugh Beg*. Leiden: E. J. Brill

Kary-Niazov, T. N. (1950). *Astronomicheskaya shkola Ulugbeka* (The astronomical school of Ulugh Beg) (in Russian). Moscow: Akademia Nauk SSSR. (Second enlarged edition in Kary-Niazov, Izbrannye trudy [Collected works]. Vol. 6. Tashkent: FAN, 1967.)

—— (1976). "Ulugh Beg." In *Dictionary of Scientific Biography*, edited by Charles Coulston Gillispie. Vol. 13, pp. 535-537. New York: Charles Scribner's Sons

Kennedy, E. S. (1956). "A Survey of Islamic Astronomical Tables." *Transactions of the American Philosophical Society*, n.s., 46, pt. 2: 121-177, esp. 125-126 and 166-167. (Reprint, Philadelphia: American Philosophical Society, 1989.)

—— (1960). "A Letter of Jamshid al-Kashi to His Father: Scientific Research and Personalities at a Fifteenth Century Court." *Orientalia* 29: 191-213.

(Reprinted in E. S. Kennedy, et al., *Studies in the Islamic Exact Sciences*, edited by David A. King and Mary Helen Kennedy. Beirut: American University of Beirut, 1983, pp. 722-744.)

—— (1998). "Ulugh Beg as Scientist." Chapter 10 in *Astronomy and Astrology in the Medieval Islamic World*. Aldershot: Ashgate. (Describes the marginal note by Ulugh Beg in a manuscript of Kashi's Zij.)

Knobel, Edward Ball (1917). *Ulugh Beg's Catalogue of Stars: Revised from All Persian Manuscripts Existing in Great Britain, with a Vocabulary of Persian and Arabic Words*. Washington: Carnegie Institution of Washington.

Krisciunas, Kevin (1992). "The Legacy of Ulugh Beg." In *Central Asian Monuments*, edited by H. P. Paksoy, pp. 95–103. Istanbul: Isis. (Includes a bibliography of all publications of parts of the Zij of Ulugh Beg.)

—— (1993). "A More Complete Analysis of the Errors in Ulugh Beg's Star Catalogue." *Journal for the History of Astronomy* 24: 269-280.

Kunitzsch, Paul (1998). "The Astronomer al-Şūfi as a Source for Uluğ Beg's Star Catalogue." In *La science dans le monde iranien à l'époque islamique*, edited by Ž. Vesel, H. Beikbaghban, and B. Thierry de Crussol des Epesse, pp. 41-47. Tehran: Institut français de recherche en Iran.

Manz, Beatrice F. (2000). "Ulugh Beg." In *Encyclopaedia of Islam*. 2nd ed. Vol. 10, pp. 812-814. Leiden: E. J. Brill

Rosenfeld, B. A. and Jan P. Hogendijk (2002/2003). "A Mathematical Treatise Written in the Samarkand Observatory of Ulugh Beg." *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften* 15:25-65.

Sayılı, Aydın (1960). *The Observatory in Islam*. Ankara: Turkish Historical Society, esp. pp. 260-289.

—— (1960). *Ghiyath al-Din al Kashi's Letter on Ulugh Beg and the Scientific Activity in Samarkand*. Ankara: Turkish Historical Society

Schoy, Carl (1927). *The Trigonometric Teachings of the Persian Astronomer Abū l-Rayban Muhammed ibn Ahmed al-Birūnī, as Presented According to al-Qānūn al-Mas'ūdī*. Hanover:

Lafaire. (Reprinted in Schoy, *Contributions to Arabic-Islamic Mathematics and Astronomy*, edited by Fuat Sezgin, Vol. 2, pp. 629-746. Frankfurt am Main: Institute for the History of Arabic-Islamic Science, 1988.) (Includes an edition of parts of Ulugh Beg's sine and tangent tables.)

Sédillot, Louis P. E. Amélie (1847). *Prolégomènes des tables astronomiques d'Oloug-Beg. Publiés avec notes et variantes et précédés d'une introduction*. Paris: Firmin Didot.

—— (1853). *Prolégomènes des tables astronomiques d'Oloug-Beg. Traduction et commentaire*. Paris: Firmin Didot.

Shevchenko, Mikhail Yu (1990). "An Analysis of Errors in the Star Catalogues of Ptolemy and Ulugh Beg." *Journal for the History of Astronomy* 21: 187-201.