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Ulugh Beg: Muḥammad Ṭaraghāy ibn Shāhrukh ibn Tīmūr

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Born **Sulṭāniyya, (Iran), 22 March 1394**

Died **near Samarqand, (Uzbekistan), 27 October 1449**

Ulugh Beg (Turkish for “great prince”) was governor of Transoxiana and Turkestan and, during the last 2 years of his life, Timurid Sultan. However, he is mostly remembered as a patron of mathematics and astronomy. In Samarqand, 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 first-born son of Shāhrukh (youngest son of the infamous conqueror Tīmūr or Tamerlane) and his first wife Gawharshād. He was raised at the court of his grandfather and, at the age of 10, was married to his cousin Agha Bīkī, whose mother was a direct descendent of Chingiz Khan. Thus Ulugh Beg could use the epithet Gūrgān, “royal son-in-law,” which had originally been used for Chingiz's son-in-law.

In the years after Tīmūr's death in 1405, Ulugh Beg became governor of Turkestan and Transoxiana, the most important cities of which were the cultural centers Samarqand 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 Marāgha Observatory that had been directed by **Ṭūsī**. In 1417, he founded in Samarqand a *madrasa* (religious school or college) that can still be seen on the Registan Square. At this institution, unlike other *madrasas*, mathematics and astronomy were among the most important subjects taught. The most prominent teacher was **Qāḍīzāde al-Rūmī**, who was joined somewhat later by **Kāshī**.

Two extant letters by Kāshī to his father in Kāshān make 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 reach scientific truth.

In 1420, Ulugh Beg founded his famous astronomical observatory on a rocky hill outside the city of Samarqand. Its circular main building, beautifully decorated with glazed tiles and marble plates, 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 Fakhrī sextant after that of **Khujandī**). On the scale of this instrument, which partially lay in an underground slit with a width of half a meter, 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 Samarqand are astrolabes, quadrants, and sine and versed sine instruments.

Although Ulugh Beg was the director of the Samarqand Observatory, Kāshī was in charge of observations until his death in 1429, after which he was succeeded by Qāḍīzāde, who died after 1440. The observational program was completed by **Qūshjī**, who had studied in Kirmān (southeastern Iran) before returning to Samarqand. The results of the observations made under Ulugh Beg include the measurement of the obliquity of the ecliptic as 23° 30'17" (the actual value at the time was 23° 30'48") and that of the latitude of Samarqand as 39° 37'33" N. (modern value: 39° 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 stayed in operation for little more than 30 years. It was finally destroyed in the 16th century and completely covered by earth in the course of time. In 1908, archaeologist V. L. Vyatkin recovered the underground part of the Fakhrī 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 *Zīj-i Ulugh Beg*, *Zīj-i Jadīd-i Sulṭānī*, or *Zīj-i Gūrgānī*. In the introduction, Ulugh Beg acknowledges the collaboration of Qāḍīzāde, Kāshī, and Qūshjī, who were undoubtedly responsible for the underlying observations as well as the computation of the tables. The *Zīj* 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 *Zīj* 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 precision given, whereas the intermediate values, calculated by means of quadratic interpolation, contain incidental errors of at most two units. Also most of the planetary tables in the *Zīj* were 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 in 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 *Zīj* was highly influential and continued to be used in the Islamic world until the 19th century. It was soon translated into Arabic by Yaḥyā ibn ʿAlī al-Rifāʿī and into Turkish by ʿAbd al-Raḥmān ʿUthmān. Reworkings for various localities were made in Persian, Arabic, and Hebrew by scholars such as ʿImād al-Dīn ibn Jamāl al-Bukhārī (Bukhara), **Ibn Abī al-Fatḥ al-Ṣūfī** (Cairo), Mullā Chānd ibn Bahāʾ al-Dīn and Farīd al-Dīn al-Dihlawī (both Delhi), and Sanjaq Dār and Husayn Qusʿa (Tunis). Commentaries to the *Zīj* were written by Qūshjī, **Mīram Chelebī**, **Bīrjandī**, and many others. Hundreds of manuscript copies of the Persian original of Ulugh Beg's *Zīj* are extant in libraries all over the world. Already in 17th-century England, various parts of the *Zīj* 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 Kāshī's *Khāqānī Zīj* presents a clever improvement of a spherical astronomical calculation. A *Risāla fī istikhrāj jayb daraja wāḥida* (Treatise on the extraction of the sine of 1°) has been attributed to Ulugh Beg on the basis of a citation in Bīrjandī, although most manuscripts of this work mention Qāḍīzāde 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 Muḥammad ibn Jaʿfar al-Kirmānī, who is known to have worked at the

observatory in Samarqand, was originally dedicated to Ulugh Beg.

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

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