Ulugh-beg | Encyclopedia.com

(*b*. Sulṭāniyya, Central Asia, 22 March 1394; *d*, near Samarkand, Central Asia [now Uzbek S.S.R.], 27 October 1449)

astronomy.

Ulugh Beg, which means "great prince," was a title that replaced his original name, Muhammad Taragay. He was raised at the court of his grandfather, Tamerlane, and from 1409 was the ruler of Maverannakhr, the chief city of which was Samarkand.

In contrast with his grandfather, Ulugh Beg was not interested in conquest but gained fame as a scientist. At Samarkand in 1420 he founded a *madrasa*, or institution of higher learning, in which astronomy was the most important subject. Ulugh Beg himself selected the scientists who taught there, first interviewing them to determine their qualifications. His *madrasa* differed from others of that time both in the content and in the level of the subjects taught there. Besides Ulugh Beg, the lecturers included Salāh al-Dīn Mūsā ibn Mahmūd (Qādī Zāda), and Ghiyāth al-Dīn Jamshīd al-Kāshī.

Four years after founding the *madrasa*, Ulugh Beg erected a three-story observatory. At the instigation of the jurists, however, the building was reduced to ruins by the beginning of the sixteenth century, and in time apparently disappeared. Its precise location remained unknown until 1908, when the archaeologist V. L. Vyatkin found its remains.

The main instrument of the observatory proved to be–not a quadrant, as Vyatkin thought–but a "Fakhrī sextant." A trench about two meters wide was dug in a hill, along the line of the meridian, and in it was placed a segment of the arc of the instrument. The part that is preserved, which was in the trench, consists of two parallel walls faced with marble, fifty-one centimeters apart.

The main use of the Fakhrī sextant was in determining the basic constants of astronomy: the inclination of the ecliptic to the equator, the point of the vernal equinox, the length of the tropical year, and other constants arising from observation of the sun. Thus it was built chiefly for solar observations in general and for observations of the moon and the planets in particular (an arc of 60° is sufficient). Other instruments used were an armillary sphere, a triquetrum, an astrolable, and a *shāmila*(an instrument serving as astrolabe and quadrant).

With the aid of the Fakhrī sextant one could determine at noon every day the meridional height of the sun, its distance from the zenith, and its declination; and from this information one could deduce the latitude and the inclination of the ecliptic, such that between the latitudeϕ the distance from the zenith z, and the declinationδ there is the known relationship $\phi=z+\delta$. For example, letting$\acute{\varepsilon}$ be the inclination of the ecliptic, the distance from the zenith at noon on the day of the summer solstice is $z_1=\Phi-\acute{\varepsilon}$ and on the day of the winter solstice $z_2=\phi+\acute{\varepsilon}$,equations that lead to$\acute{\varepsilon}$ = x 1/2 (z_2-z_1). The value obtained by Ulugh Beg for the inclination of the ecliptic, ε = 23° 30' 17", differs by only 32" from the true value (for his time).[1] According to him, the latitude of Samarkand was 39°37'33".[2]

The radius of the Fakhrī sextant in Ulugh Beg's observatory was 40.04 meters, which made it the largest astronomical instrument in the world of that type. On the are of the sextant are divisions in which 70.2 centimeters corresponds to one degree; 11.7 millimeters (or, if rounded, 12 millimeters) represents one minute; 1 millimeter is five seconds: and 0.4 millimeter is two seconds. It has been experimentally established that with unrestricted time for observation and sufficient training of the observer, the value of the threshold of angular discrimination can be considered as two to five seconds. Thus the choice of the scale of the main instrument, and its smallest divisions, was made with consideration for the limits of angular discrimination.

An important result of the scientific work of Ulugh Beg and his school was the astronomical tables called the Zīj of Ulugh Beg or the Zīj–i *Gurgāni* (Guragon, the title of Genghis Khan's son-in-law, was also used by Ulugh Beg). This work, originally written in the Tadzhilk language, consists of a theoretical section and the results of the observations made at the Samarkand observatory; the latter include actual tables of calendar calculations, of trigonometry, and of the planets, as well as a star catalog.

The basis of Ulugh Beg's trigonometric tables was the determination of sin 1° with great accuracy. One of the methods of solving this problem was Ulugh Beg's, and another was that of Al-;Kāshī[3]. Both lead to the solution of the third-degree algebraic equation with the form.

$x^3 + ax + b = 0$,

where $x = \sin 1°$. Solving this equation by an original method of subsequent approximations, one obtains

$x = \sin 1° = 0.017452406437283571$.

In his trigonometric tables Ulugh Beg gives the values of sines and tangents for every minute to 45°, and for every five minutes from 45° to 90° the values of cotangents are given for every degree. Comparing the values of the sines of any angles–for example, 20°, 23° and 26°–with the corresponding true values, we obtain the following:

According to Ulugh Beg	True Value
20° 0.342020142	20° 0.342020143
23° 0.390731129	20° 0.390731128
26° 0.438371147	26° 0.438371147

Also strikingly accurate is the study of the yearly movements of the five bright plants known in the time of Ulugh Beg, as is evident bleow:[4]

According to Ulugh Beg	True Value
Saturn 12°13’39”	12°13’36” (d’ Alembert)
Jupiter 30° 20’ 34”	30°20’31” (d’ Alembert)
Mars 191°17’15”	191°17’10” (Lalande)
Venus 224°17’32”	224°17’30” (Lalande)
Mercury 53°43’13”	53°43’3” (Lalande)

Thus the difference between Ulugh Beg’s data and that of modern times relating to the first four planets falls within the limits of two to five seconds.

In the case of Mercury the difference is somewhat larger–ten seconds at most–because, of the planets mentioned, Mercury has the greatest orbital velocity. In addition, the eccentricity of its orbit is 0.206–that is, it is considerable in comparison with the eccentricity of the four other planets–while the greatest visible angular distance of Mercury from the sun’s disk is only about 28°. These peculiarities of the planet make observation of it with the naked eye fairly difficult, and consequently have an adverse effect on the accuracy of the results of observation. The yearly precession was determined by Ulugh Beg[5] to be 51.4”, while the true value is 50.2.”.

The situation is somewhat different with Ulugh Beg’s values for the positions of the stars. After that of Hipparchus, the star catalog of Ulugh Beg was the second in seventeen centuries. It contains 1,018 stars, the positions of some of which were determined mainly from observations made at the Samarkand observatory, and others from observations made before the beginning of 1437 (A.H./841).[6] The latter were taken from the star catalog of al-Sūfī, who apparently borrowed them from Ptolemy. Thus the star catalog of Ulugh Beg has great value, since it is basically original, but nevertheless was influenced by Ptolemy, at least in respect to its coordinates.

In 1941 an expedition under the leadership of T. N. Kari-Niazov discovered the tomb of Ulugh Beg in the mausoleum of Tamerlane in Samarkand. In contrast with the Islamic customs of burying the dead only in a shroud, Ulugh Beg lay fully clothed in a sarcophagus, in agreement with the prescription of the *shariat*; a man who died as a *shakhid* (martyr) had to be buried in his clothes. On the skeleton, traces of his violent death are clear: the third cervical vertebra was severed by a sharp instrument in such a way that the main portion of the body and an arc of that vertebra were cut off cleanly; the blow, struck from the left, also cut through the right corner of the lower jaw and its lower edge.

NOTES

1. Ulugh Beg, *Zīj Guragoni*, Biruni Institute of Oriental Studies, Uzbek S.S.R. Academy of Sciences, MS 2214, 1.11a.

2.*Ibid*., 1. 102b.

3. Birjantsi, *Sharh, Zīj Guragoni*, Biruni Institute of Oriental Studieds, Uzbek S.S.R. Academy of Sciences, MS 704, 1. 49a.

4. J.B.J. Delambre, *Historie de l’ astronomie indenne orientale* (Paris, 1787), 155.

5. Ulugh Beg., *op. cit*., II. 117b, 118a.

6.*ibid*.

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