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Khujandī: Abū Maḥmūd Ḥāmid ibn al-Khiḍr al-Khujandī

Glen Van Brummelen

Born **Khujand, (Tajikstan)**, ***circa* 945**

Died **1000**

Khujandī was an astronomer of some repute who constructed a variety of instruments and contributed to the mathematics supporting astronomical work. He is best known for the first very large mural quadrant that was intended to make solar observations of unprecedented accuracy. Only a few details are known of his life; he was likely one of the khans of Khujanda in Transoxania and was supported by the Būyid ruler Fakhr al-Dawla.

Khujandī's towering achievement, the giant mural sextant near Rayy, was perhaps the most ambitious instrument of its time. Named *al-suds al-Fakhrī* (after its sponsor Fakhr al-Dawla), it consisted of 60° of a meridian arc about 43 m in diameter, built at and below ground level. A small aperture in the roof of the building that housed the instrument allowed a cone of the Sun's rays to shine through. A circle with crosshatch lines was placed on the rays that fell onto the scale in order to determine their center. The scale was marked to 10', making it the first instrument capable of measuring with a precision better than minutes.

In 994 Khujandī used the *suds al-Fakhrī* to measure meridian transits near solstices; from this he obtained the value $\varepsilon = 23;32,19°$ for the obliquity of the ecliptic, and a value of 35;34,38.45° for the latitude of Rayy (accurate to within one'). On the basis of earlier determinations of ε, Khujandī decided that ε is a variable quantity, a conclusion with which **Bīrūnī** disagreed. In his *Taḥdīd al-amākin*, Bīrūnī discusses Khujandī's work in detail. He argues that the measurements failed to produce the expected accuracy because the building settled between the summer and winter solstices, causing the height of the aperture in the roof to drop. After the failure of the *suds al-Fakhrī*, the observational program probably continued with armillary spheres and other instruments, and Khujandī eventually produced the *Zīj al-Fakhrī* (an astronomical handbook) on the basis of his results. (A partially extant Persian *zīj* written 200 years later may also derive from Khujandī's observations.) Although the large instrument was an immediate failure, it was a model for similar instruments at the observatories in Marāgha and Samarqand in the 13th and 15th centuries, respectively. These avoided the problem of settling by using different construction materials.

Astronomical instruments are a recurring interest in Khujandī's other works. A treatise entitled *The Comprehensive Instrument* describes an invention called a *shāmila* designed to replace the astrolabe or a quadrant. It was not universal in the sense that it was restricted for use in a particular range of terrestrial latitudes.

Two geometric methods of drawing azimuth circles on an astrolabe are credited to Khujandī by other medieval authors. He constructed an astrolabe in 984/985, which is one of the earliest still extant. It is considered to be one of the most important surviving astronomical instruments.

Khujandī composed several mathematical works, among them a text on geometry and a flawed proof of Fermat's last theorem for $n = 3$. He is also one of several competing claimants to the rule of four quantities, a theorem in spherical trigonometry that was simpler than Menelaus' theorem and, for many Muslim astronomers, replaced it as the basic tool of spherical astronomy.

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