

Biographical Encyclopedia of Astronomers

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Tusi: Abu Jafar Muhammad ibn Muhammad ibn al-Hasan Nasir al-Din al-Tusi

Born Tus, (northeast Iran), 17 February 1201

Died Baghdad, (Iraq), 25 June 1274

Nasir al-Din al-Tusi's major scientific writings in astronomy, in which he worked to reform Ptolemaic theoretical astronomy, had an enormous influence upon late medieval Islamic astronomy as well as the work of early-modern European astronomers, including Nicholas Copernicus. Tusi wrote over 150 works, in Arabic and Persian, that dealt with the ancient mathematical sciences, the Greek philosophical tradition, and the religious sciences (law [*fiqh*], dialectical theology [*kalām*], and Sufism). He thereby acquired the honorific titles of *khwāja* (distinguished scholar and teacher), *ustādh al-bashar* (teacher of mankind), and *al-mu'allim al-thalith* (the third teacher, the first two being Aristotle and Fārābī). In addition, Tūsi was the director of the first major astronomical observatory, which was located in Marāgha (Iran).

Tūsi was born into a family of Imāmī (Twelver) Shia. His education began first at home; Both Tūsi's father and his uncles were scholars who encouraged him to pursue *al-'ulum al-shariyya* (the Islamic religious sciences) as well as the *'ulum al-awa'il* (the rational sciences of the ancients). He studied philosophy (*hikma*) and especially mathematics in Tus, but eventually traveled to Nishapur (after 1213) to continue his education in the ancient sciences, medicine, and philosophy with several noted scholars. Among the subjects he studied were the works of Ibn Sina, who became an important formative influence. Tusi then traveled to Iraq, where his studies included legal theory. In Mosul (sometime between 1223 and 1232), one of his teachers was Kamal al-Din ibn Yunus (died 1242), a legal scholar also renowned for his expertise in astronomy and mathematics.

In the early 1230s, after completing his education, Tūsi found patrons at the Ismāīlī courts in eastern Iran; he eventually relocated to Alamūt, the Ismāīlī capital, and witnessed its fall to the Mongols in 1256. Tūsi then served under the Mongols as an advisor to the Ilkhanid ruler Hūlāgū Khan, becoming court astrologer as well as minister of religious endowments (*awqāf*). One major outcome was that Tūsi oversaw the construction of an astronomical observatory and its instruments in Maragha, the Mongol headquarters in Azerbaijan, and he became its first director. The Maragha Observatory also comprised a library and school. It was one of the most ambitious scientific institutions established up to that time and may be considered the first full-scale observatory. It attracted many famous and talented scientists and students from the Islamic world and even from as far away as China. The observatory lasted only about 50 years, but its intellectual legacy would have repercussions from China to Europe for centuries to come. Indeed, it is said that Ulugh Beg's childhood memory of visiting the remnants of the Maragha Observatory as a youth contributed to his decision to build the Samarkand Observatory. Mughal observatories in India, such as those built by Jai Singh in the 18th century, clearly show the influence of these earlier observatories, and it has been suggested that Tycho Brahe might have

been influenced by them as well. In 1274, Tūsī left Maragha with a group of his students for Baghdad.

Tūsī's writings are both synthetic and original. His reviews (*tahārīr*) of Greek and early Islamic scientific works, which included his original commentaries, became the standard in a variety of disciplines. These works included Euclid's *Elements*, Ptolemy's *Almagest*, and the so-called *mutawassitāt* (the "Intermediate Books" that were to be studied between Euclid's *Elements* and Ptolemy's *Almagest*) with treatises by Euclid, Theodosius, Hypsicles, Autolycus, Aristarchus, Archimedes, Menelaus, Thabit ibn Qurra, and the Banū Mūsā. In mathematics, Tūsī published a sophisticated "proof" of Euclid's parallel postulate that was important for the development of non-Euclidean geometry, and he treated trigonometry as a discipline independent of astronomy, which was in many ways similar to what was accomplished later in Europe by Johann Müller (Regiomontanus). Other important and influential works include books on logic, ethics, and a famous commentary on a philosophical work by Ibn Sīnā.

In astronomy, Tūsī wrote several treatises on practical astronomy (*taqwīm*), instruments, astrology, and cosmography/theoretical astronomy (*'ilm al-hay'a*). He also compiled a major astronomical handbook (in Persian) entitled *Zīj-i ilkhānī* for his Mongol patrons in Maragha. Virtually all these works were the subject of commentaries and supercommentaries, and many of his Persian works were translated into Arabic. They were influential for centuries, some still being used into the 20th century.

Tūsī's work in practical astronomy, as well as his *Zīj-i ilkhānī*, were not particularly original or innovative. This was not the case with his work in planetary theory. There, he sought to rid the Ptolemaic system of its inconsistencies, in particular its violations of the fundamental principle of uniform circular motion in the heavens. Tūsī set forth an astronomical device (now known as the Tūsī couple) that consisted of two circles, the smaller of which was internally tangent to the other, which was twice as large. The smaller circle rotated twice as fast as the larger one and in the opposite direction. Tūsī was able to prove that a given point on the smaller sphere would oscillate along a straight line. By incorporating this device into his lunar and planetary models, Tūsī reproduced Ptolemaic accuracy while preserving uniform circular motion. A second version of this couple could produce (approximately) oscillations on a large circular arc, allowing Tūsī to address irregularities in Ptolemy's latitude theories and lunar model.

These models were first found in Tūsī's Persian treatise *Hall-i mushkilat-i Mu'iniyya* (Solution of the difficulties in the *Mu'iniyya*), written for his Ismā'īlī patrons, and were further developed and incorporated years later in his famous Arabic work *al-Tadhkira fī ilm al-haya* (Memoir on astronomy), composed during his years with the Mongols. Tūsī's devices are of major significance for several reasons. First, they produced models that adhered to both physical and mathematical requirements; the two versions of the Tūsī couple, from the perspective of mathematical astronomy, allowed for a separation of the effect of the planet's distance from its speed (which had been tied together in the Ptolemaic models). Tūsī was thus able, for example, to circumvent Ptolemy's reliance on circular motion to produce a rectilinear, latitudinal effect. Second, Tūsī's new models greatly encouraged and influenced the work of Islamic astronomers, such as his student Qutb al-Din al-Shirazi and Ibn al-Shatir (14th century), as well as the work

of early-modern European astronomers such as Copernicus. The Tusi couple also appears in Sanskrit and Byzantine texts.

Tusi also influenced his astronomical and cosmological successes with his discussion of the Earth's motion. Although he remained committed to a geocentric universe, Tusi criticized Ptolemy's reliance on observational proofs to demonstrate the Earth's stasis, noting that such proofs were not decisive. Recent research has revealed a striking similarity between Tusi's arguments and those of Copernicus

Tūsi was committed to purifying knowledge in all its forms, and he tried to reconcile the intellectual traditions of late Greek Antiquity with his Islamic faith. As was the case with many Islamic scientists, he held that the certainty of the exact mathematical sciences, especially astronomy and pure mathematics, was a means toward understanding God's creation.

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