From: Thomas Hockey et al. (eds.). *The Biographical Encyclopedia of Astronomers, Springer Reference*. New York: Springer, 2007, pp. 1153-1155

http://dx.doi.org/10.1007/978-0-387-30400-7_1398

Ṭūsī: Abū Jaʿfar Muḥammad ibn Muḥammad ibn al-Ḥasan Naṣīr al-Dīn al-Ṭūsī

F. Jamil Ragep

Born **Ṭūs (northeast Iran), 17 February 1201**

Died **Baghdad (Iraq), 25 June 1274**

Naṣīr al-Dīn al-Ṭūsī'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**. Ṭūsī 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-muʿallim al-thālith* (the third teacher, the first two being **Aristotle** and **Fārābī**). In addition, Ṭūsī was the director of the first major astronomical observatory, which was located in Marāgha (Iran).

Ṭūsī was born into a family of Imāmī (Twelver) Shīʿa. His education began first at home; both Ṭūsī's father and his uncles were scholars who encouraged him to pursue *al-ʿulūm al-sharʿiyya* (the Islamic religious sciences) as well as the *ʿulūm al-awāʾil* (the rational sciences of the ancients). He studied the branches of philosophy (*ḥikma*) and especially mathematics in Ṭūs, but eventually traveled to Nīshāpūr (after 1213) in order to continue his education in the ancient sciences, medicine, and philosophy with several noted scholars; among the things he studied were the works of **Ibn Sīnā**, who became an important formative influence. Ṭūsī then traveled to Iraq where his studies included legal theory; in Mosul (sometime between 1223 and 1232), one of his teachers was Kamāl al-Dīn ibn Yūnus (died: 1242), a legal scholar who was also renowned for his expertise in astronomy and mathematics.

In the early 1230s, after completing his education, Ṭūsī found patrons at the Ismāʿīlī courts in eastern Iran; he eventually relocated to Alamūt, the Ismāʿīlī capital, and witnessed its fall to the Mongols in 1256. Ṭūsī then served under the Mongols as an advisor to Īlkhānid ruler Hūlāgū Khan, becoming court astrologer as well as minister of religious endowments (*awqāf*). One major outcome was that Ṭūsī oversaw the construction of an astronomical observatory and its instruments in Marāgha, the Mongol headquarters in Azerbaijan, and he became its first director. The Marāgha 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 Marāgha Observatory as a youth contributed to his decision to build the Samarqand 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 Ṭūsī left Marāgha with a group of his students for Baghdad.

Ṭūsī's writings are both synthetic and original. His recensions (*taḥārīr*) 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 *mutawassiṭāt* (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**, **Thābit ibn Qurra**, and the **Banū Mūsā**. In mathematics, Ṭūsī published a sophisticated "proof" of Euclid's parallels postulate that was important for the development of non-Euclidian 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 of Ibn Sīnā.

In astronomy, Ṭūsī wrote several treatises on practical astronomy (*taqwīm*), instruments, astrology, and cosmography/theoretical astronomy (*ʿilm al-hayʾa*). He also compiled a major astronomical handbook (in Persian) entitled *Zīj-i Īlkhānī* for his Mongol patrons in Marāgha. 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.

Ṭūsī's work in practical astronomy, as well as his *Zīj-i Īlkhānī*, 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. Ṭūsī set forth an astronomical device (now known as the Ṭūsī-couple) that consisted of two circles, the smaller of which was internally tangent to the other that was twice as large. The smaller rotated twice as fast as the larger and in the opposite direction. Ṭūsī 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, Ṭūsī reproduced Ptolemaic accuracy while preserving uniform circular motion. A second version of this couple could produce (approximately) oscillation on a great circle arc, allowing Ṭūsī to deal with irregularities in Ptolemy's latitude theories and lunar model.

These models were first found in Ṭūsī's Persian treatise *Ḥall-i mushkilāt-i Muʿīniyya* (Solution of the difficulties in the *Muʿīniyya*), written for his Ismāʿīlī patrons, and were further developed and incorporated years later in his famous Arabic work *al-Tadhkira fī ʿilm al-hayʾa* (Memoir on astronomy), composed during his years with the Mongols. Ṭūsī'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 Ṭūsī couple, from the perspective of mathematical astronomy, allowed for a separation of the effect of distance of the planet from its speed (which had been tied together in the Ptolemaic models). Ṭūsī was thus able, for example, to circumvent Ptolemy's reliance on a circular motion to produce a rectilinear, latitudinal effect. Second, Ṭūsī's new models greatly encouraged and influenced the work of Islamic astronomers, such as his student **Quṭb al-Dīn al-Shīrāzī** and **Ibn al-Shāṭir** (14th century) as well as the work of early-modern European astronomers such as Copernicus. The Ṭūsī couple also appears in Sanskrit and Byzantine texts.

Ṭūsī also influenced his astronomical and cosmological successors with his discussion of the Earth's motion. Although he remained committed to a geocentric universe, Ṭūsī 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 Ṭūsī's arguments and those of Copernicus.

Ṭūsī was committed to pursing 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 certitude of the exact mathematical sciences, especially astronomy and pure mathematics, was a means toward understanding God's creation.

Selected References

Al-Ṭūsī, Naṣīr al-Dīn (1998). *Contemplation and Action (Risālah-i Sayr wa sulūk)*, edited and translated by S. J. Badakhchani. London: I. B. Tauris.

Kusuba, Takanori and David Pingree (2002). *Arabic Astronomy in Sanskrit: Al-Birjandī on* Tadhkira II, *Chapter 11 and Its*

Sanskrit Translation. Leiden: E. J. Brill. (For the translation of a part of a commentary on Tūsī's *Tadhkira* into Sanskrit.)

Ragep, F. Jamil (1987). “The Two Versions of the Tūsī Couple.” In *From Deferent to Equant: A Volume of Studies in the History of Science in the Ancient and Medieval Near East in Honor of E. S. Kennedy*, edited by David A. King and George Saliba, pp. 329–356. Annals of the New York Academy of Sciences, Vol. 500. New York: New York Academy of Sciences.

——— (1993). *Naṣīr al-Dīn al-Ṭūsī's* Memoir on Astronomy (*al-Tadhkira fī ʿilm al-hayʾa*). 2 Vols. New York: Springer-Verlag.

——— (2000). “The Persian Context of the Tūsī Couple.” In *Naṣīr al-Dīn al-Ṭūsī: Philosophe et savant du XIIIe siècle*, edited by N. Pourjavady and Ž. Vesel, pp. 113–130. Tehran: Institut français de recherche en Iran/Presses universitaires d'Iran.

——— (2000). “Al-Ṭūsī, Naṣīr al-Dīn: As scientist.” In *Encyclopaedia of Islam*. 2nd ed. Vol. 10, pp. 750–752. Leiden: E. J. Brill.

——— (2001). “Ṭūsī and Copernicus: The Earth's Motion in Context.” *Science in Context* 14: 145–163.

——— (2004). “Copernicus and His Islamic Predecessors: Some Historical Remarks.” *Filozofski vestnik* 25: 125–142.

Ridawī, M. M. (1976). *Aḥwāl wa-āthār... Naṣīr al-Dīn*. Tehran: Farhang Iran.

Rosenfeld, B. A. and Ekmeleddin Ihsanoğlu (2003). *Mathematicians, Astronomers, and Other Scholars of Islamic Civilization and Their Works (7th–19th c.)*. Istanbul: IRCICA, pp. 211–219.

Sayılı A. (1960). *The Observatory in Islam*. Ankara: Turkish Historical Society. (On the Marāgha Observatory, see pp. 187–223.)

Corrections/Additions