Taqī al-Dīn Abū Bakr Muḥammad ibn Zayn al-Dīn Maʿrūf al-Dimashqī al-Ḥanafī

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Born **Damascus, (Syria), 14 June 1526**

Died **Istanbul, (Turkey), 1585**

Taqī al-Dīn was the founder and the director of the Istanbul Observatory and worked in the fields of mathematics, astronomy, optics, and mechanics. He made various astronomical instruments and was the first astronomer to use an automatic–mechanical clock for his astronomical observations. He advanced the arithmetic of decimal fractions and used them in the calculation of astronomical tables.

Taqī al-Din began his studies, as was normal, with the basic religious sciences and Arabic. Later on, he continued his religious studies and studied the mathematical sciences with scholars in Damascus and Egypt, including most significantly his father. It is probable that Taqī al-Dīn's teacher in mathematics was Shihāb al-Dīn al-Ghazzī whereas the one in astronomy was *Muḥammad ibn Abī al-Fatḥ al-Ṣūfī*. Taqī al-Dīn himself states in several of the forewords to his books that he was particularly interested in the mathematical sciences during his education.

Taqī al-Dīn, after completing his education, taught for a short while at various *madrasas* (schools) in Damascus. He, together with his father Maʿrūf Afandī, came to Istanbul around the year 1550 where he benefited from his association with a number of prominent scholars. Taqī al-Dīn would shortly return to Egypt where he spent most of the next 20 years. A brief trip back to Istanbul, also around 1550, brought him into the company of the Grand Vizier Samīz ʿAlī Pasha, who allowed him to use his private library and clock collection. Taqī al-Dīn would benefit from this association when ʿAlī Pasha was appointed governor of Egypt, where he held positions as a teacher and judge (*qāḍī*) in Egypt. Encouraged to deal with mathematics and astronomy by a grandson of **ʿAlī Qūshjī**, who collected and gave Taqī al-Dīn works by his grandfather, by **Jamshīd al-Kāshī**, and by **Qāḍizāde**, as well as various observation instruments, Taqī al-Dīn undertook a serious pursuit of astronomy and mathematics. While a judge in Tinnīn, Egypt, he made astronomical observations by means of an astronomical instrument that he mounted in a well that was 25-m deep.

Taqī al-Dīn returned to Istanbul in 1570 and was appointed head astronomer (*Müneccimbası*) by Sultan Selīm II upon the death of **Muṣṭafā ibn ʿAlī al-Muwaqqit** in 1571. He continued his observations in a building situated on a height overlooking Tophane or in Galata Tower and gained the support of several high officials. This led to an imperial edict by Sultan Murad III in early 1579 to build an observatory, which was located on a height overlooking Tophane where the French

palace is located today. Important astronomical books and instruments were collected there. Little is known about the size, shape, and so on, but we do have magnificent depictions of the scholars at work and of the astronomical instruments in use (in *Ālāt-i raṣadiyya li-Zij-i Shāhinshāhiyya* [Istanbul Univesity, TY, MS 1993] and in 'Alā' al-Dīn Manṣūr al-Shīrāzī's *Shāhinshahnāme* [Istanbul University, TY, MS 1404]). Apart from the observatory building, we hear of a well called *çah-i raṣad* that was also used by Taqī al-Dīn. Unfortunately the observatory did not last long. Due to political reasons, as well as Taqī al-Dīn's incorrect astrological prognostications, it was demolished by the state on 22 January 1580.

Taqī al-Dīn's most important work in astronomy is entitled *Sidrat muntahā al-afkār fī malakūt al-falak al-dawwār (= al-Zij al-Shāhinshāhī)*. This work was prepared according to the results of the observations in Egypt and Istanbul in order to correct and complete *Zij-i Ulugh Beg*, a project originally conceived in Egypt and furthered by the building of the Istanbul Observatory. In the first 40 pages of the work, Taqī al-Dīn deals with trigonometric calculation. This is followed by discussions of astronomical clocks, heavenly circles, and so forth. In the following parts, he treats observational instruments and their use, the observations of lunar and solar motions, and trigonometric functions calculated according to sexagesimal. As was normal in the Islamic astronomical tradition, Taqī al-Dīn used trigonometric functions such as sine, cosine, tangent, and cotangent rather than chords. Following the work done at the Samarqand Observatory, he developed a new method to find the exact value of sin 1°, which Jamshīd al-Kāshī had put into the form of an equation of third degree. Additionally, Taqī al-Dīn employed the method of "three observation points," which he was the first to use for calculating solar parameters; apparently **Tycho Brahe** was aware of his work. For determining the longitudes and latitudes of the fixed stars, he used Venus, Aldebaran, and α Virginis (Spica), which are near the ecliptic (rather than the Moon), as reference stars. As a result of his observations, he found the eccentricity of the Sun to be 2° 0' and the annual motion of apogee 63". Taqī al-Dīn's values turn out to be more precise than those of **Nicolaus Copernicus** and Brahe. This provides evidence for the precision of Taqī al-Dīn's methods of observation and calculation. It is thus a pity that the destruction of the observatory meant that Taqī al-Dīn was unable to complete his observation program. Indeed in the absence of a conclusion to this *Zij*, it can probably be concluded that the book was never completed.

Taqī al-Dīn's second most important work on astronomy is a *zij* entitled *Jarīdat al-durar wa kharīdat al-fikar*. In this work, for the first time we find the use of decimal fractions in trigonometric functions. He also prepared tangent and cotangent tables. Moreover, in this *zij*, as in another of his *zij*es entitled *Tashīl zij al-a'shāriyya al-shāhinshāhiyya*, Taqī al-Dīn gave the parts of degree of curves and angles in decimal fractions and carried out the calculations accordingly. Excluding the table of fixed stars, all the astronomical tables in this *zij* were prepared using decimal fractions.

In addition, Taqī al-Dīn has some other astronomical works of secondary importance. One of them is *Dustūr al-tarjīḥ li-qawā'id al-tasṭīḥ*, which is about the projection of a sphere onto a plane as well as other topics in geometry. Another of his works is *Rayḥānat al-rūḥ fī rasm al-sā'āt 'alā mustawī al-suṭūḥ*, which deals with sundials drawn on marble surfaces and their features. This book was commented upon by his student Sirāj al-Dīn 'Umar ibn Muḥammad al-Fāriskūrī (died: 1610) under the title *Nafḥ al-fuyūḥ bi-sharḥ rayḥānat al-rūḥ*; the commentary was translated into Turkish by an unknown writer in the beginning of the 17th century.

In addition to his 20 books on astronomy, Taqī al-Dīn wrote one book on medicine and zoology, three on physics-mechanics, and five on mathematics. He has a monograph entitled *Risāla fī 'amal al-mīzān al-ṭabī'ī* on the specific gravity of substances and **Archimedes**' hydrostatic experiments. All of his books are in Arabic.

Taqī al-Dīn's works on physics and mechanics, besides being interesting in their own right, also have connections with astronomy. In 1559 while in Nablus, he wrote his *al-Kawākib al-durriyya fī waḍ' al-*

bankāmāt al-dawriyya, which dealt with mechanical-automatic clocks for the first time in the Islamic and Ottoman world. In the foreword, Taqī al-Dīn mentions that he benefited from using Samiz ʿAlī Pasha's private library and his collection of European mechanical clocks. In this work, Taqī al-Dīn discusses various mechanical clocks from a geometrical–mechanical perspective. His second book on mechanics is the one he wrote when he was 26, *al-Ṭuruq al-saniyya fī al-ālāt al-rūḥāniyya*. In this work, Taqī al-Dīn focuses on the geometrical-mechanical structure of clocks previously examined by the **Banū Mūsā** and Abū al-ʿIzz al-Jazarī. In the field of physics and optics, Taqī al-Dīn wrote *Nawr ḥadīqat al-abṣar wa-nūr ḥaqīqat al-Anẓar*, which dealt with the structure of light, its diffusion and global refraction, and the relation between light and color.

In his mathematical treatises, Taqī al-Dīn dealt with various aspects of trigonometry, geometry, algebra, and arithmetic. In the latter, he carried on the work of Kāshī in developing the arithmetic of decimal fractions both theoretically and practically.

Taqī al-Dīn was a successor to the great school of Samarqand and, following the lead of ʿAlī Qūshjī, tended toward a more purely mathematical approach in his scientific work that was beginning to abandon Aristotelian physics and metaphysics. Taqī al-Din's most significant achievement in the history of Islamic and Ottoman astronomy is his foundation of the Istanbul Observatory and his activities there. Besides using established instruments and techniques, he developed a number of new ones as well, including his use of the automatic–mechanical clock. Carrying on the work of his Islamic predecessors, Taqī al-Dīn's application of decimal fractions to trigonometry and astronomy stands as another important contribution to astronomy and mathematics.

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