

The Contribution of Taqi al-Din bin Muhammad bin Ma'ruf to the Development Of Falak in Turkey During the Ottoman Dynasty

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Abstract:

This article examines Taqi al-Din's contribution to the development of Falak Science in Turkey during the Ottoman Turkish Dynasty. Taqi al-Din was a famous astronomer in the 16th century who had an essential role in developing Falak science in Turkey at that time. The research method used is historical and literary analysis. The results showed that Taqi al-Din played an essential role in improving astronomical instruments in Turkey that he considered obsolete, such as the Quadrant (Rubu' Mujayyab), Sekstan, Astrolabe, Sundial, and Water Clock. Taqi al-Din replaced these tools with mechanical clocks. In addition, he also initiated the construction of the first observatory in the Ottoman Turkish Dynasty (Istanbul Observatory), which was used to determine prayer times and observe the movement of celestial bodies. The results of these observations were recorded in the form of tables and had the highest accuracy value at that time. In addition, Taqi al-Din also contributed to the Hijri calendar by compiling Zij-i Sidrat al-Muntaha and Zij-i Khidrat ad-Durar wa Jariyat al-Fikar to replace Ulugh Beik's inaccurate Zij Sultani.

Keywords: Taqi al-Din, Science of Falak, Contribution, Ottoman Turkish Dynasty

Introduction

Falak, or Islamic astronomy, is essential in developing human civilization. In the golden era of Islam, science flourished in various regions, including Turkey, where the Ottoman Dynasty ruled. At that time, Turkey, as the center of power of the Ottoman Dynasty, played an essential role in trade, politics, and the development of science in the region. Until now, Turkey has still paid attention to science by initiating the criteria of the Turkish Global Islamic Calendar (KIG) as a visibility criterion in efforts to unify the Hijri calendar.

During the Ottoman Turkish Dynasty, one of the figures who contributed to the development of science in Turkey was Taqi al-Din bin Muhammad bin Ma'ruf. Taqi al-Din lived in the 16th century when science and scientific discoveries rapidly developed in the Islamic world. Of the various literature that discusses Muslim scientists, especially those who discuss the science of falak, very few writings discuss Taqi al-Din bin Muhammad bin Ma'ruf and his contribution to the development of Falak.

Some of the writings that tell about Taqi al-Din are Encyclopedias and research on time and history. Among them is Stephen P. Blake's *Time in Early Modern Islam* research. Blake speaks about Taqi al-Din in this book as part of a chapter on calendars in the Ottoman Empire.¹ Another paper by Ihsan Fazlioglu is entitled *Taqi al-Din Ibn Ma'ruf: Survey on his Works and Scientific Method*. In this paper, Ihsan talks about Taqi al-Din's work and the scientific methods he used.² The works tell of Taqi al-Din as part of the history of astronomy in Ottoman Turkey.

In this article, we will examine in depth the contribution of Taqi al-Din to the development of Falak Science in Turkey. By understanding Taqi al-Din's contribution, we can understand how science developed in Turkey at that time and appreciate the scientific legacy it left behind. This research is expected to provide deeper insight into the important role of Taqi al-Din in the development of science in Turkey during the Ottoman Dynasty and highlight his success in developing astronomical tools, building observatories, and compiling the Hijri calendar.

The authors use two research methods to analyze Taqi al-Din bin Muhammad bin Ma'ruf's contribution to the development of science in Turkey during the Ottoman Dynasty: the historical method and literature analysis. Historical methods were used to study and analyze Taqi al-Din's contribution to the development of science in Turkey. The author collects historical sources relevant to Taqi al-Din's life and contributions and then conducts criticism and analysis of these sources. Furthermore, the author analyzes the social, political, and intellectual context during the Ottoman Dynasty to understand the influence and impact of Taqi al-Din's contribution to the development of Falak. The literature analysis method is used to study the works of Taqi al-Din and other researchers related to the development of science in Turkey. Using historical methods and literature analysis, this article is expected to present a comprehensive understanding of Taqi al-Din's contribution to the development of science in Turkey during the Ottoman Dynasty.

Biography of Taqi al-Din bin Muhammad bin Ma'ruf

Taqi al-Din had the full name Taqi al-Din Abu Bakr Muhammad ibn Qadhi Ma'ruf ibn Ahmad al-Shami al-'Asadi al-Rasid (1526-1585). He was

¹ Stephen P. Blake, *Time in Early Modern Islam* (New York: Cambridge University Press, 2013), 66–75.

² Ihsan Fazlioglu, 'Taqi Al-Din Ibn Ma'ruf: Survey on His Works and Scientific Method', *Muslim Heritage*, 2008, <https://muslimheritage.com/taqi-al-din-works-sci-method/>.

an Ottoman Turkish astronomer from Damascus who worked in Istanbul. He is known as al-Rasid (observer) due to his fame as an astronomer, observer, and head of the Istanbul Observatory. He also excelled in various other scientific branches, such as mathematics, optics, mechanics, and engineering.³

Taqi al-Din was born in Damascus to a family of Turkish descent. He received his education in Damascus and Cairo. In Cairo, he studied Islamic theology, philosophy, and law.⁴ After receiving his education in theology, where he studied with scholars in Damascus and Cairo, including his father, Ma'ruf Efendi, he became interested in rational sciences such as astronomy and astrology.⁵ He has worked as a teacher at various madaris and served as a qadi (judge) in Nablus (in Palestine), Damascus, and Cairo. He served as a religious judge in a town near Cairo before moving to Istanbul sometime in the late 1540s or early 1550s.⁶ He produced several important works in astronomy and mathematics during his stay in Egypt and Damascus.

In 1570, Taqi al-Din moved from Cairo to Istanbul to pursue his astronomical and astrological career. One year later (1571–1572), he was appointed by Suleiman's successor, Selim II (1566–1574), as chief astronomer (*munecimbashi*) after the death of Mustafa ibn Ali al-Muwaqqit.⁷ A *munecimbashi* heads a large office. He and his subordinates performed basic astronomical and astrological tasks for the imperial family. They were responsible for determining auspicious dates and hours for important events such as imperial accessions, wars, weddings, and ship launches. They also track and interpret unusual astronomical events such as comets, earthquakes, and eclipses (both solar and moon). Taqi al-Din⁸ maintained excellent and close relations with many important scholars and statesmen, most notably Khojja Sa'd al-Din Efendi (d. 1559), who was Murad's childhood teacher and

³ Salim Ayduz, 'Taqi Al-Din Ibn Ma'ruf: A Bio-Bibliographical Essay', Muslim Heritage, 2008, <https://muslimheritage.com/taqi-al-din-bio-essay/>.

⁴ Blake, *Time in Early Modern Islam*, 66.

⁵ Salim Ayduz and Huseyin Sen, 'Taqī Al Dīn Ibn Ma'rūf', in *The Oxford Encyclopaedia of Philosophy, Science and Technology in Islam*, II (New York: Oxford University Press, 2014), 315–17.

⁶ Blake, *Time in Early Modern Islam*, 66.

⁷ Ihsan Fazlioglu, 'Alī Al-Muwaqqit: Muslih Al-Dīn Mustafā Ibn 'Alī Al-Qustantīnī Al-Rūmī Al-Hanafī Al-Muwaqqit', in *Biographical Encyclopaedia of Astronomers*, ed. Hoki Thomas, I (New York: Springer, 2007), 33.

⁸ L. Menage, 'The Beginnings of Ottoman Historiography', in *Historians of the Middle East*, ed. Bernard Lewis and P.M. Holt (London: Oxford University Press, 1962), 171–72; Blake, *Time in Early Modern Islam*, 70.

dedicated to Sultan Murad III (r. 1574-1595) by Grand Vizier Mehmed Pasha Sokolovic (d. 1579).⁹

In his early years as a *muneccim*¹⁰, Taqi al-Din supported himself by casting horoscopes, answering questions, choosing days and times, and constructing and interpreting almanacks (*takwim*). An Ottoman *Muneccim* had the important task of preparing an annual almanack (*takwim*).¹¹ He immediately showed his outstanding skills and talents. He wrote twenty-five works in Arabic on arithmetic, algebra, optics, astrolabe, observation instruments, sundials, and clocks. Taqi al-Din also wrote a critique of Ptolemy (*Almagesty*) and compiled two of his *zij* (tables), which later became data for *takwim* (Hijri calendar). Taqi al-Din continued to work in the *Muneccimbashi's* office until he died in 1585.¹²

Istanbul Observatory

Taqi al-Din is known as an Ottoman astronomer. In addition to his extraordinary genius, he established the first observatory in the Ottoman Dynasty, the Istanbul Observatory.¹³ This observatory became an important observation center for determining prayer times and observing the motion of celestial bodies.

At that time, Taqi al-Din, as a *muneccimbashi* informed Sultan Murad III that the Ulugh Beik Astronomical Table (*Ulugh Beik Zij*) contained specific observational errors that resulted in calculations based on those tables. Taqi al-Din suggests that such mistakes can be corrected with new observations. So, he proposed building an observatory in Istanbul to fix the error. Sultan Murad III granted Taqi al-Din's request due to his interest in astronomy and astrology and the support of Sokullu Muhammad Pasha (Grand Vizier) and Khwajah Saad al-Din (Murad's childhood teacher). Sultan Murad III granted Taqi al-Din additional grants to the new institution. Sultan Murad wanted to be proud of being the first Ottoman ruler to establish an observatory. Sultan Murad III ordered that construction of the observatory begin immediately. He

⁹ Ayduz and Sen, 'Taqī Al Dīn Ibn Ma'rūf'.

¹⁰ In the Ottoman Empire, *muneccim* was also a good master of time. He obtained his training as an apprentice in the home of an accomplished practitioner who was under one of the *muneccims in the local* *muvakkithane*, or, if he was talented, in the office of the *muneccimbashi* (chief imperial astronomer/astrologer). See Blake, *Time in Early Modern Islam*, 69.

¹¹ Menage, 'The Beginnings of Ottoman Historiography', 1962, 171-72; Blake, *Time in Early Modern Islam*, 70.

¹² Ayduz and Sen, 'Taqī Al Dīn Ibn Ma'rūf'.

¹³ Blake, *Time in Early Modern Islam*, 67.

provided all the financial assistance needed for the observatory construction project.¹⁴ Finally, a new observatory was completed in 1577, occupying a hill in the European part of the city, overlooking the Golden Horn and the Bosphorus.

The observatory was the first observatory in Istanbul during the reign of Ottoman Sultan Murad III (1574-1595), and there was a library containing various books on astronomy and mathematics.¹⁵ The Istanbul Observatory consists of two buildings, a large and a small building. The large building contains offices and apartments for 15 astronomers and a library. The small building is a small observatory with the most sophisticated equipment at that time. The observatory was built at a higher location than Tophane in Istanbul.¹⁶

The observatory was designed to meet astronomers' needs, and it included a library and a workshop for designing and producing instruments. Taqi al-Din dreams of making this new observatory rival the great observatories of the past, such as the Tusi observatory in Maragha and Ulugh Beg in Samarqand. The observatory was later considered one of the largest observatories in the Islamic world and was completed in 1579.¹⁷

The observatory was arguably the most advanced in the world then, superior in size and equipment, and comparable to Tycho Brahe's (1546-1601) Uraniborg observatory, built in 1576. The striking similarity between the two is the instruments inside, including the sextant (*mushabbaha bi'l-manatiq*), wooden quadrants, and astronomical clocks.¹⁸ In his astronomical table entitled *Sidratu Muntaha al-Afkar fi Malakut al-Falak al-Dawwar*, Taqi al-Din says he began astronomical activities in Istanbul with 15 assistants in 1573;¹⁹ consisting of 7 observers (*rasid*), four clerks, and four assistants.²⁰

In September 1578, a comet appeared in the sky of Istanbul. Taqi al-Din considers this a rare opportunity. He worked for several nights

¹⁴ Ayduz, 'Taqi Al-Din Ibn Ma'ruf: A Bio-Bibliographical Essay'.

¹⁵ Ayduz.

¹⁶ Blake, *Time in Early Modern Islam*, 71-72.

¹⁷ Ayduz and Sen, 'Taqi Al Dīn Ibn Ma'rūf'.

¹⁸ FSTC, 'Astronomical Instruments of Tycho Brahe and Taqi Al-Din', *Muslim Heritage*, 2005, <https://muslimheritage.com/tycho-brahe-and-taqi-al-din/>.

¹⁹ Sevim Tekeli, 'Trigonometry in Two Sixteenth Century Works: The *De Revolutionibus Orbium Coelestium* and the *Sidra Al-Muntaha*', in *History of Oriental Astronomy* (Cambridge: Cambridge University Press, 1987), 209-14.

²⁰ Ayduz and Sen, 'Taqi Al Dīn Ibn Ma'rūf'.

without stopping to figure out the implications of the comet.²¹ He then conveyed the results of his observations to the Sultan. Taqi al-Din gave glad tidings to the Sultan of the conquest of Persia as his astrological interpretation of the appearance of comets in the skies of Istanbul.

This event turned out to be the beginning of the struggle for power at the highest level of the Ottoman court. A rival faction, led by the prominent religious leader, Sheikh al-Islam Qadizada, attacked the Grand Vizier's party. Qadizada stated that Taqi al-Din's interpretation of astrology was wrong. The victory over the Safavids was short-lived; the plague had devastated several cities, and more than one important person had died. In addition, he said that the observatory is immoral because, through the observatory, they uncover the secrets of nature. Observatories also often brought misfortune upon their founders, such as the beheaded Ulugh Beg and his dynasty, Il-Khanid, which lasted only seventy years.²²

Sheikh al-Islam eventually won the power struggle. In January 1580, less than three years after its completion, Murad III ordered the observatory destroyed. Before making a decision, Murad III consulted Taqi al-Din. Taqi al-Din realized he had been caught on the wrong side of the power struggle. He then convinced the sultan that his work was done. *Zij-i Sultani's* table has been improved through observations.²³

A recently published report (*talhis*) of the grand vizier Sinān Pasha (d. 1596) to Sultan Murād III shows how the sultan and vizier tried to keep Taqī al-Dīn out of the hands of 'ulama', who wanted to try Taqī al-Dīn for heresy. The vizier informed the Sultan that despite the sultan's orders, Taqī al-Dīn insisted on going to Syria and warned the sultan that if he went there, he might still be recognized by the 'ulama' there and put on trial. Finally, Taqi al-Din knew enough to accept defeat gracefully. The destruction of the Istanbul observatory, when Ulugh Beg's revision was far from over, must have been heartbreaking. He has five more years to live, but they can't be happy.

The Istanbul Observatory continued to function until January 22, 1580, the date it was destroyed. They use religious arguments to justify such acts of destruction, but their roots lie in specific political conflicts.²⁴

²¹ Sayili, *The Observatory in Islam* (Ankara: Turk Tarih Kumumu Basimevi, 1988), 291.

²² ISSUED, 291–92.

²³ Sayili, 293.

²⁴ Blake, *Time in Early Modern Islam*, 73.

Innovation of Astronomical Instruments

Taqi al-Din is known for initiating the construction of the Istanbul observatory and for his initiation of astronomical instruments, including mechanical clocks. During the Ottoman Empire, they paid great attention to daily prayer times. After the conquest of Istanbul, *muwakkithane* (timekeeping offices) were established in the courtyards of most local mosques as a tool to help indicate daily prayer times. Inside are astronomical instruments such as quadrants, astrolabes, sextants, octans, sundials, and water clocks to indicate the exact time.²⁵ However, Taqi al-Din considered these tools old-fashioned and wanted to replace them with mechanical clocks.²⁶

The determination of prayer times at the time of the Prophet Muhammad was done by observing celestial bodies, namely the sun. Islamic astronomers (*muneccim*), after the time of Prophet Muhammad, produced tables of the sun, moon, and stars as a result of their observations of the movements of celestial bodies. The tables were the most accurate in medieval Eurasia. As for instruments of Harun al-Rashid's time, such as sundials and water clocks, they were the most sophisticated at that time.

However, in the early modern period, astronomers (*muneccim*) were obsessed with producing such obsession timeliness as determining the time of birth, eclipse, equinox, solstice, rising of the moon, or setting of the sun. This obsession led Safavid and Ottoman astronomers to turn to mechanical clocks, one of which was Taqi al-Din.²⁷

The purpose of Taqi al-Din's switching to mechanical clocks was to determine prayer times precisely without observing the movements of celestial bodies and without using quadrants.²⁸ At that time, the tools to show the exact time were lacking. The clocks used at that time were still in the form of hourglasses, the results of which were only approximate, so they could not be used for a long time. Likewise, with water clocks, the

²⁵ E. Ihsanoglu, 'Ottoman Science: The Last Episode in Islamic Scientific Tradition and the Beginning of the European Scientific Tradition', in *Science, Technology, and Learning in the Ottoman Empire* (London: Ashgate Publishing House, 2004), 18.

²⁶ Blake, *Time in Early Modern Islam*, 66.

²⁷ Blake, 73–74.

²⁸ Sevim Tekeli, *The Clocks in the Ottoman Empire in the 16th Century and Taqi Al-Din's "The Brightest Stars for the Construction of the Mechanical Clocks"* (Ankara: Ankara Universitesi Basimevi, 1966), 141–42.

results are approximate. It is difficult to make a water clock and impossible to carry it from one place to another.²⁹

The first mechanical clocks that came to the court of the Ottoman dynasty in the early sixteenth century came from the Netherlands, Hungary, France, and Germany. However, according to Ogier Ghizelin de Busbecq, the arrival of the clock was not received enthusiastically. Turkey is indeed a nation with greater readiness to take advantage of Western inventions, such as cannons and mortars, than other nations. However, they could not accept printing and setting public hours. This is because they consider that the holy book will no longer be sacred if it is printed. The existence of public clocks would shift the authority of the muezzins, and their ancient rites would be disrupted.³⁰

However, modern scholars disagree with Busbecq's opinion. The existence of tower clocks (large public clocks) was still sporadic in the sixteenth and seventeenth centuries, not because the Ottoman Turks were not interested in mechanical clocks nor because of problems of religious authority. But more because it relates to the cost and accuracy of mechanical clocks. This is evidenced by the extensive construction of mechanical clocks appearing in public squares throughout the empire in the late nineteenth century as a symbol of the Ottoman Turks' desire for modernization.³¹

In contrast to these scholars, the treatise Taqi al-Din, completed in the last year of Suleiman's administration, mentions a discriminatory interest in punctuality technology. Of the five mechanical clocks mentioned by Taqi al-Din, three do not have much space for such mechanical clocks, namely tower, pocket, and domestic clocks. Two types of domestic clocks began to appear in the palaces and mansions of Istanbul around 1550, and by the end of the century, it became pretty common. The first type is more significant, standing on brackets or affixed to the wall. The second type is smaller, found on the table.³²

In addition to the three mechanical clocks mentioned earlier, two types dominate Taqi al-Din's treatise: astronomical and observational. The astronomical clock, which reproduces the movements of seven celestial bodies, was built according to the Ptolemaic universe theory,

²⁹ Tekeli, 143.

³⁰ Tekeli, 143.

³¹ Jason Godwin, *Lords of the Horizon: A History of the Ottoman Empire* (New York: Henry Holt, 1999), 306.

³² Tekeli, *The Clocks in the Ottoman Empire in the 16th Century and Taqi Al-Din's "The Brightest Stars for the Construction of the Mechanical Clocks"*, 133–35.

with the Earth as its center. Taqi al-Din's astronomical clock shows the face of the moon, the days of the week, the relationship between the sun and the moon, the position of the sun in the zodiac, azimuth, latitude, and ascension of certain stars, and prayer times.³³ This astronomical clock was made in 971 AH (1563-1564). The prayer times indicated by the clock made by Taqi al-Din are the times of dawn prayer, Friday prayer, midday (dhuhr), afternoon (asr), evening (maghrib and isha'), and midnight prayer.³⁴

The observation clock (observational) is a unique astronomical clock whose purpose is to set the right time for observing celestial objects. It has three buttons, namely hours, minutes, and seconds. This observation clock was the most accurate watch of its day, thus making the zij Taqi al-Din the most appropriate clock for the movement of the sun, moon, planets, and stars. Ottoman interest in mechanical clocks maintained the Taqi al-Din. At the end of the sixteenth century, a watchmaker's guild was found in the imperial court.³⁵

In the Ottoman Empire, the Ottoman commitment was to use timekeeping technology that was practical, technological, and durable. In the sixteenth and seventeenth centuries, the Ottomans had little interest in tower clocks because they seemed inaccurate and difficult to maintain. On the contrary, Taqi al-Din's motivation is scientific. For him, increasingly accurate clocks were a necessary start to increasingly precise astronomical observations. Finally, the results of his mechanical clock were more precise than Tycho Brahe in Uraniborg. Taqi al-Din has built the most accurate timepiece in the Eurasian world.³⁶

The purpose of building the new observatory in Istanbul was to renew Zij-i Sultani, so Taqi al-Din produced various ancient astronomical instruments used to make observations at the Istanbul observatory and made new astronomical instruments. In general, observation instruments at Istanbul observatories can be divided into two types: permanent and portable instruments. Kuni instruments used in the Istanbul Observatory include³⁷:

³³ Tekeli, 129–35, 175–81.

³⁴ Tekeli, 184.

³⁵ E. Ihsanoglu, 'Some Remarks on Ottoman Science and Its Relation with European Science and Technology up to the End of the 18th Century', in *Science, Technology, and Learning in the Ottoman Empire* (London: Ashgate Publishing House, 2004), 55–56.

³⁶ Blake, *Time in Early Modern Islam*, 74.

³⁷ Sevim Tekeli, 'The Instruments of Istanbul Observatory', *Muslim Heritage*, 2008, <https://muslimheritage.com/instruments-istanbul-observatory/>.

1. An armillary ball (*dhât al-halaq*). This globe consists of six circles that measure latitude and longitude. The radius of the circle is more than four meters in size. Everything is placed on a pedestal called the horizon. The horizon is placed on six columns, with the lower end attached to another bench like a horizon. Globes with this shape were commonly used in Europe in the 16th century.
2. A mural quadrant (*libna*). This quadrant is used to observe the declination of the sun and stars. Taqi al-Din preferred this mural quadrant to *Suds-i Fakhri* and the two bows used by earlier astronomers. These two bows are brass quadrants with a radius of six meters placed on the wall and erected on the meridians.
3. Semicircle azimuth (*dhât al-samt wa-'l-irtifâ'*). This instrument is used to measure the height and azimuth of the stars. The instrument consists of a copper circle indicating the horizon and a circle perpendicular to the horizon.
4. A parallax ruler or *triquetrum*. This instrument is used to observe lunar parallax. This tool is made of three long pieces of wood, where the first wood is perpendicular to the horizon, the second wood is connected at the head of the first wood with an axis, and the third wood has a division of chords placed and nailed near the base of the first wood.
5. Wooden quadrant (*rubu'*). This instrument is used to measure the height of the stars and their distance to the zenith. This tool is a quarter circle and is made of a wooden ruler. The basic form is the same as *rubu' mujayyab* used in Indonesia until today.
6. Dioptra (*dhât al-thuqbatayn*). This tool is used to measure the diameter of celestial bodies and eclipses. It looks like a ruler with two holes at the ends of both sides.

In addition to these old instruments, Taqi al-Din also invented new observational instruments that he added and used in the observatory. Among such instruments are the following³⁸:

1. Sextant (*mushabbaha bi-'l manâtiq*). This instrument is used to measure distances between stars. Taqī al-Dīn's *Mushabbaha bi'l manâtiq* resembles the sextant's Tycho Brahe. Both are considered to be among the great achievements of 16th-century astronomy. *Mushabbaha bi-l manâtiq* consists of three rulers. Two of

³⁸ Salim Ayduz, 'Ottoman Contributions to Science and Technology', Muslim Heritage, 2008, <https://muslimheritage.com/ottoman-contributions-to-science-and-technology/>.

them are attached as triquetrum rulers. An arc was mounted at the end of one of the rulers. Taqī al-Dīn made this instrument to observe the radius of Venus mentioned in the tenth book of *Ptolemy's Almagest*.

2. Instrument with cords (*dhât al-awtâr*). This tool is used to determine the autumn and spring equinoxes. The instrument consists of a rectangular base and four columns. Both columns are fixed on the base so that a rope is stretched between them. One side is equal to the latitude cosine of the place, and the other is equal to the sinus. A hole is made in each of these parts. Then, there is a rope hung from these holes with a plumb.
3. Observational clocks. As mentioned earlier, this clock is a mechanical clock made by Taqi al-Din. The clock is a wooden wall indicator that he installed in the observatory. This clock was more accurate than before and is considered one of the most important discoveries in applied astronomy in the 16th century. In *Sidrat al-muntaha*, the mechanical clock of Taqi al-Din is made with a dial that can already indicate hours, minutes, and seconds. Taqi al-Din divides each minute into five seconds.³⁹

In comparison, the instruments used by Taqi al-Din in his observatory and those used by Tycho Brahe are primarily similar in shape. Still, some of Taqi al-Din's instruments are larger and more precise. For example, the mural quadrant (*libna*) is used to observe the sun's and stars' declination. The Taqi al-Din quadrant is formed of two brass quadrants with a radius of six meters each, placed on a wall and erected on the meridian. The same instrument Brahe used was only two meters in diameter.

Three people are assigned to each instrument when making observations. Two people are in charge of operating the instrument, and one person writes down the results.⁴⁰ In his observations, Taqī al-Dīn integrated the astronomical traditions of Damascus and Samarkand. While using the above astronomical instruments at the Istanbul Observatory, Taqi al-Din made observations to correct the Ulugh Beik Astronomical Table (*Zij-i Sultani*). He also made various observations of solar and lunar eclipses. He also observed a comet visible in the sky over Istanbul for one month in September 1578.

³⁹ Aydin Sayili, *The Observatory in Islam* (Ankara: Türk Tarih Kumumu Basimevi, 1991), 289–305.

⁴⁰ Blake, *Time in Early Modern Islam*, 71.

Using the new methods he developed and the equipment he invented, Taqī al-Dīn could make innovative observations and generate new solutions to astronomical problems. He replaced decimal-based systems with sexagesimal systems and prepared trigonometric tables based on decimal fractions. His observations showed that he could determine the degree of the ecliptic as $23^{\circ} 28' 40''$, which is very close to the current value of $23^{\circ} 27'$. He used a new method to calculate the parameters of the sun. He determined that the magnitude of the annual movement of the sun's peak was 63 seconds. This value is close to the current value of 61 seconds. The method used by Taqī al-Dīn can be said to be more precise than the methods of Copernicus (24 seconds) and Tycho Brahe (45 seconds).⁴¹

The observational activities carried out at the Istanbul Observatory for a short time between 1577 and 1580 were compiled in work by Taqī al-Dīn entitled *Sidrat Muntahā'l-Afkār fī Malakūt al-Falak al-Dawwār*. Taqī al-Dīn's observations are more precise and accurate than astronomer Tycho Brahe's. In addition, some of the instruments that Taqī al-Dīn had at the Istanbul Observatory were of superior quality to those of Tycho Brahe.⁴²

Contributions to the Hijri Calendar

During the Ottoman Empire, the Hijri calendar was the main calendar used to regulate the day in Turkey, which began when the sun went down. The day is divided into two, that is, every twelve hours. The first part is from sunrise to sunset. The second part starts from sunset to sunrise. The days of the week amount to 7 days, with the first day being Friday. Other days, they use traditional names.⁴³

In certain situations in the Ottoman Empire, the months of the Julian calendar were used instead of the Hijri month. The Julian calendar contains 365.25 days a year, adopted by Julius Caesar in 45 BC. This calendar replaces the lunisolar calendar used before, whereas, in the lunisolar calendar, there is one month of intercalation (insert) periodically. Under the Ottoman Empire, the Julian calendar or Roman calendar (Rumi Takvim) first appeared as part of Bayezid I's (1481-1512)

⁴¹ Ayduz and Sen, 'Taqī Al Dīn Ibn Ma'rūf'.

⁴² Tekeli, 'The Instruments of Istanbul Observatory'; FSTC, 'Astronomical Instruments of Tycho Brahe and Taqī Al-Dīn'.

⁴³ Ihsanoglu, 'Some Remarks on Ottoman Science and Its Relation with European Science and Technology up to the End of the 18th Century', 56; Raphaela Lewis, *Everyday Life in Ottoman Turkey* (London: Batsford, 1971), 120.

solar finance era (Maliye Takvim). The twelve Roman months were transliterated into Ottoman Turkish as Yanar, Febrar, Mart, Abril, Mayıs, Yunyus, Yulyus, Augustus, Septuris, Uhturis, Nuvuros, and Decuris.⁴⁴ The Julian calendar was restricted chiefly to fiscal and accounting offices, not to public texts (such as histories, sequences, or inscriptions).

The earliest Ottoman calendars were created for the imperial family, and the time frame was short. The first two years, from 1444 to 1446, were produced for Sultan Murad II (1421-1451). Based on Ulugh Beg's *zij-i Sultani*, they open the calendar with a brief history of the prophets, early caliphs, and rulers of the Seljuk, Karaman, and Ottoman dynasties. After that, the overall predictions for the year are presented, followed by astronomical and astrological information for each day.⁴⁵

Over time, the Ottoman calendar became longer and more complicated. By the mid-sixteenth century, the Ottoman calendar had a standard format similar to that produced in the Mughal and Safavid empires. There are twenty-four pages, one double page for each month. The right column lists the days of the week and their dates in various calendars (Hijra, Yazdegird, and Rumi). On the far right are historical, religious, and cultural records, such as the beginning of delivery and commemoration seasons and Christian, Muslim, and Jewish festivals. The left-hand column records the zodiac positions of the sun, moon, and five planets. On the far left are astrological predictions such as good, bad, or indifferent days. Each almanack in the Ottoman calendar begins with the positions of the seven celestial bodies in the *Nau Ruz* and the horoscopes for the year.

Taqi al-Din and other Ottoman munecims became deeply dissatisfied with Ulugh Beik's *Zij-i Sultani* in the late sixteenth century. *Zij-i Sultani* has been used for almost 150 years and is considered outdated. This calendar based on *Zij* is becoming increasingly inaccurate. Thus, 1575 Taqi al-Din proposed to Sultan Murad III (1574-1595) to build a new observatory and compile a new *zij*. Finally, the Istanbul Observatory was built. To realize Taqi al-Din's goal of fully revising Ulugh Beg's *Zij-i Sultani*, he and his men began initial observations in 1573 and worked for seven years after that (through the completion of the observatory in 1577 and for three very productive years after that).

⁴⁴ L. T. Darling, *Revenue-Raising and Legitimation: Tax Collection and Financial Administration in the Ottoman Empire, 1560-1660* (Leiden: E. J. Brill, 1997), 135.

⁴⁵ L. Menage, 'The Beginnings of Ottoman Historiography', in *Historians of the Middle East*, ed. Bernard Lewis and P.M. Holt (London: Oxford University Press, 1962), 171-72.

From these seven years of observational work, Taqi al-Din and his team came up with two new zij, as follows⁴⁶:

1. The first *Zij* was *Zij-i Sidrat Muntaha al-Falak al-Dawar* (The Frontier of Celestial Science – 1577/78-1580), also called *az-Zij al-Shahinshahi*.

This work was compiled based on the observations of Taqi al-Din in Egypt and Istanbul to correct and complement the work of Ulugh Beik. The first 40 pages of this work deal with trigonometric calculations. This was followed by an explanation of astronomical clocks, celestial circles, and information about the three eclipses observed by Taqi al-Din in Cairo and Istanbul. This work also explains the definition of observation tools and methods, observation of the motion of the moon and sun, as well as the examination of sine and trigonometric functions calculated according to sexagesimal notation. This book does not have a conclusion chapter (*khatima*), so it is said that this work is still incomplete.

Taqi al-Din uses trigonometric functions such as sine cosine, tangent, and cotangent in this book. He also developed a new method for finding the exact value of Sine 1° , which was put into the form of an equation of the third degree. He also used the three-point observation method, a new method for calculating solar parameters. To calculate the latitude and longitude of fixed stars, he used the planets Venus, Aldebaran (alpha or brightest star in the constellation Taurus) and Spica Virginis near the ecliptic. Based on these observations, he produced $2^\circ 0'$ for the Sun's eccentricity and $63''$ for its peak annual motion. Compared with the current value, this value is more precise than the values of Copernicus and Brahe. This shows the accuracy of Taqi al-Din's method of observation and calculation.

2. The second *Zij* was *Jaridat al-Durar wa Kharidat al-Fikar* (Compilation of the Best Pearls and Ideas – 1584). This work uses decimal fractions and trigonometric functions first recorded in astronomical tables. Taqi al-Din prepared the tangent-cotangent table in this work. In addition, in this *zij*, which is also written in another *zij* entitled *Tashil Zij al-A'sariyya ash-Shahinsyahi* (Tafsir Table Based on the Decimal System of the Sultan – 1580), Taqi al-Din states the parts of the degrees of curves and angles in decimal

⁴⁶ Fazlioglu, "Taqi Al-Din Ibn Ma'ruf: Survey on His Works and Scientific Method".

fractions with precise calculations. In addition, he also prepared all astronomical tables in decimal fractions in this *Zij*.

From the beginning, Taqi al-Din realized that the Astronomical Tables used to compile the Hijri calendar used in Ottoman at that time, called Ulugh Beik's *Zij Sultani*, were inaccurate and needed improvement. Taqi al-Din is committed to improving the Hijri calendar to match the movements of the sun and moon and providing a more accurate calendar for the Muslim community. Although rudimentary, these two works of Taqi al-Din made a significant contribution as a solid scientific basis for exact calculations of time and the Hijri calendar in the Ottomans.

Nevertheless, Taqī al-Dīn's influence at the time was limited. This can be seen from the relatively small number of copies of his work, indicating that his works are not widely circulated. Only a few commentaries (*syarh*) about his works are known. However, one of his works and part of his library reached Western Europe relatively quickly due to the manuscript-collecting efforts of Jacob Golius, a professor of Dutch Arabic and mathematics from Leiden University, who travelled to Istanbul in the early seventeenth century.⁴⁷

Nevertheless, Taqi al-Din's contributions through his works have left a significant legacy in science and dating in Turkey during the Ottoman Dynasty. His continued contributions have provided a solid foundation for more accurate calculations of time and the Hijri calendar and influenced how Muslims understand and practice their religion in the context of time. His works are also a source of inspiration for modern scientists and astronomers who want to understand the motion of celestial bodies and make accurate observations. His development of astronomical instruments, the establishment of observatories, and the improvement of the Hijri calendar provided a strong foundation for the science of astronomy and astronomy as we know it today.

Conclusion

Taqi al-Din was essential in developing science in Turkey during the Ottoman Empire. Taqi al-Din is a famous astronomer with remarkable and accurate types and observations. He is also renowned for initiating the construction of the Istanbul observatory, the invention of mechanical clocks, and his work that influenced the accuracy of the Hijri calendar. Taqi al-Din initiated the construction of the first observatory in the

⁴⁷ Ayduz and Sen, 'Taqī Al Dīn Ibn Ma'rūf'.

Ottoman Turkish Dynasty (Istanbul Observatory). This observatory is used to determine prayer times and observe the movement of celestial bodies. Observations at the observatory were made with various instruments. Some ancient instruments used in the Istanbul observatory are an armillary sphere, a mural quadrant, an azimuthal semicircle, a parallactic ruler, a wooden quadrant, and dioptra. There are three new instruments invented by Taqi al-Din for observations at the Istanbul Observatory: the sextant, the instrument with cords, and the astronomical clock. The observations collected from the Istanbul observatory with various instruments were then recorded in tables (*zij*) with the highest accuracy value at that time. Taqi al-Din produced two main works based on his observations, namely *Zij-i Sidrat al-Muntaha* and *Zij-i Khidrat ad-Durar wa Jariyat al-Fikar*. This two *zij* contributed to the accurate timing and calendar of the Hijri, replacing Ulugh Beik's inaccurate *Zij Sultani*. These two works of Taqi al-Din became a solid scientific basis for accurate calculations of time and the Hijri calendar in the Ottomans. The development of astronomical instruments, the establishment of observatories, and the improvement of the Hijri calendar by Taqi al-Din provided a strong foundation for the science of astronomy and astronomy that we know today.

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