
A Brief History of Observatories in the Islamic World (800-1600)

Sejarah Singkat Observatorium di Dunia Islam (800–1600)

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Abstract

This paper examines the historical and philosophical role of observatories in the Islamic world (800–1600 CE). More than scientific centres, these institutions embodied Islam's metaphysical commitment to knowledge ('ilm) and cosmic order. Under leaders like Caliph al-Ma'mun, observatories became state-sponsored platforms for studying celestial bodies not only as physical objects but as divine signs (āyāt). Using classical sources and modern scholarship, the study situates these observatories within Islam's unified worldview, where science and spirituality were intertwined. It argues that Islamic scientific progress must be understood within its civilisational and theological framework.

Keywords

Islamic observatories, 'ilm, al-Ma'mun, astronomy, cosmology, āyāt, Islamic civilisation, metaphysics, science and spirituality, historical philosophy.

Abstract

Makalah ini mengkaji peran historis dan filosofis observatorium di dunia Islam antara tahun 800–1600 M. Lebih dari sekadar pusat ilmiah, institusi ini mewakili komitmen metafisik Islam terhadap ilmu pengetahuan ('ilm) dan keteraturan kosmik. Di bawah kepemimpinan seperti Khalifah al-Ma'mun, observatorium menjadi wadah yang didukung negara untuk mempelajari benda-benda langit, bukan hanya sebagai objek fisik, tetapi juga sebagai tanda-tanda ilahi (āyāt). Dengan menggunakan sumber klasik dan kajian modern, studi ini menempatkan observatorium dalam pandangan dunia Islam yang menyatukan ilmu dan spiritualitas. Disimpulkan bahwa kemajuan ilmiah Islam harus dipahami dalam kerangka peradaban dan teologisnya.

Keywords

Observatorium Islam, 'ilm, al-Ma'mun, astronomi, kosmologi, āyāt, peradaban Islam, metafisika, ilmu dan spiritualitas, filsafat sejarah.



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Introduction

The early medieval period was marked by dramatic shifts in power and culture across Europe and the Islamic world. In the Iberian Peninsula, Christian kingdoms experienced a significant military defeat during the Islamic conquests, which ushered in centuries of Moorish dominance. This era coincided with a period of stagnation in Western Europe, where the intellectual achievements of classical civilizations—particularly those of Rome and Greece—had faded into obscurity.

In contrast, the Islamic world was experiencing a cultural and intellectual renaissance. Arabic scholars became the inheritors and guardians of Hellenistic science, translating and expanding upon Greek texts. Astronomy, in particular, flourished as Muslim scientists not only preserved ancient knowledge but also synthesized it with their own mathematical and observational advancements. The result was a sophisticated and coherent model of the heavens, aspects of which remain relevant in modern astronomy.

The concept of the observatory—an institution specifically dedicated to celestial observation—has ancient roots. Structures such as Stonehenge in England and the Great Pyramid of Cheops in Egypt are believed to have served astronomical functions, albeit without formal scientific frameworks. It was within the Islamic Golden Age, however, that observatories became formalized scientific institutions. These centers of research marked a pivotal shift from informal skywatching to organized and systematic inquiry into the cosmos.

One of the earliest and most influential developments occurred during the reign of Caliph al-Ma'mun al-Rashid (786–833 CE), a leader renowned for his patronage of science and philosophy. Under his direction, observatories were constructed at al-Shamsiya near Baghdad and at Mount Qasiyun near Damascus. These observatories not only facilitated accurate measurements of celestial bodies but also laid the groundwork for future astronomical theories in both the Islamic and Western worlds. Their legacy illustrates the Islamic world's deep engagement with empirical science and intellectual curiosity during a period when much of Europe remained intellectually dormant.¹

Research Methodology

The present study adopts a historical-philosophical methodology, rooted in the understanding that history is not merely a record of past events

¹ Sky and Telescope USA , page 38, February 2000

but a manifestation of enduring ideas and values as expressed through time and culture. In this context, the observatory is not examined solely as a scientific edifice, but as a civilizational institution imbued with metaphysical purpose and intellectual intentionality. Rather than applying a purely positivistic or descriptive historical method, this study interprets the rise and evolution of Islamic observatories within the broader framework of Islamic cosmology and intellectual history,² as advocated by scholars like Nasr (1993) and Al-Attas (1995) Historical data is thus approached as a reflection of the Islamic worldview, wherein the heavens symbolize divine order and astronomical investigation becomes a form of worship (ibādah) and epistemological pursuit (maʿrifah)³

This methodology is informed by both primary and secondary sources. Primary accounts from classical Islamic scholars such as al-Biruni, al-Khwarizmi, and al-Battani are utilized not merely for their data but for the metaphysical assumptions embedded in their work. These sources are complemented by modern historical analyses, such as those by George Saliba (2007) and Seyyed Hossein Nasr (1992), who explore the intricate relationship between science, metaphysics, and civilizational development in Islam⁴. The inclusion of Islamic star catalogues, instruments, and architectural descriptions further serves as a means of textual and material analysis—treating instruments like the astrolabe or armillary sphere not just as tools, but as cultural artifacts representing a synthesis of intellect and faith⁵.

Furthermore, this study employs civilizational comparison as a mode of critical reflection. By comparing Islamic observatories with their Western counterparts (e.g., Maragha with Tycho Brahe’s Uraniborg, or Samarkand with Greenwich), the methodology avoids the Eurocentric narrative of linear scientific progress. Instead, it affirms what Al-Attas (1991) terms the “distinctive epistemological framework” of the Islamic intellectual tradition, where knowledge (ʿilm) is both rational and spiritual in nature⁶. This

² Seyyed Hossein Nasr, *The Need for a Sacred Science* (Albany: SUNY Press, 1993), 14–18.

³ Syed Muhammad Naquib Al-Attas, *Prolegomena to the Metaphysics of Islam* (Kuala Lumpur: ISTAC, 1995), 147.

⁴ George Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, MA: MIT Press, 2007), 34–38; Nasr, *Science and Civilization in Islam* (Harvard University Press, 1992), 98

⁵ A. I. Sabra, “Science and Philosophy in Medieval Islamic Civilization,” in *The Cambridge History of Arabic Literature: Religion, Learning and Science in the ‘Abbasid Period*, ed. M. J. L. Young (Cambridge: Cambridge University Press, 1990), 274–290.

⁶ Al-Attas, *The Concept of Education in Islam: A Framework for an Islamic Philosophy of Education* (Kuala Lumpur: ISTAC, 1991), 12–14.

comparative approach reveals how Islamic astronomers functioned not only as scientists but also as metaphysicians often constructing their theories with reference to Qur'anic cosmology, philosophical reasoning, and theological inquiry⁷. Lastly, this study treats observatories as philosophical and institutional expressions of a civilization's relationship with the cosmos. The methodology integrates architectural history, political patronage, scientific output, and cosmological symbolism to provide a holistic understanding of the observatory's function in Islamic society. Works such as those by Ibn Khaldun, along with modern commentaries by scholars like Nasr (1992) and Dhanani (1994), form the basis for understanding how the observatory reflected the Islamic pursuit of order (*niẓām*), harmony (*tawāzun*), and ultimate meaning (*ma'nā*)⁸. By grounding the research in this philosophical-historical framework, the study aspires not only to document the observatories of Islam but to uncover the spirit that gave rise to them.

Finding and Discussion

1. Shamsiyya Observatory

Shamasiya was supplied with a building, which served as residence and place of work for its astronomers. Sanad ibn Ali was one of the most important astronomers of this institution. Al-Mamun asked him to build astronomical instruments. Yahya ibn Abi Mansur & al Abbas al-Jawhari were the two other astronomers employed in this observatory. Both these scientists took part in the astronomical observations organized at Baghdad 829-30 and Damascus 832-33. Yahya was the author of *Ziji Mumtahan* while Abbas wrote commentaries on *Elements*.

Shamasiya observatory was part of the Bayt al-Hikma (House of Wisdom), which was also established by Caliph al-Mamun in Baghdad. This was called *Khizana Kutub al-Hikma* (Library of Wisdom) as it consisted of a library which carried out translations of many scientific and philosophical works. Regular weekly meetings of translators and scientists were held at Bayt al-Hikma, in this respect it was an academy like Plato's in Athens. Famous

⁷ Ibrahim Kalin, "Islam and Science: Theological Perspectives," *Islamic Studies* 43, no. 1 (2004): 15–23.

⁸ Ibn Khaldun, *Muqaddimah*, trans. Franz Rosenthal (Princeton: Princeton University Press, 1967), 330–335; Nasr, *Science and Civilization in Islam*, 122

mathematician al-Khawarizmi (780-850) who took part in the degree measurement, was at one time librarian of this science institute. He was one of the first to compute astronomical tables.

It may be of interest that some scholars were directed by al-Mamun to travel to Byzantine to purchase Greek scientific manuscripts even if at an exorbitant cost.

Astronomer Al-Biruni (973-1050) informs us that two solstice observations were made at Shamasiyya by Yahya ibn Abi Mansur (d830 Aleppo) in the year 828 AD in which al-Khwarizmi was also present. Two more observations were made next year and compared with the previous year. An armillary sphere was used in making observations, although no detailed description is given. Work lasted here for year and a half.



Armillary Sphere

Ibn Khalaf al-Marwudhi was an instrument designer who made an astrolabe. (Astrolabe is an instrument used for measuring the altitude of a heavenly body. Sextant replaced it in the 18th century) An azimuthal quadrant was used for the measurement of azimuths, and elevations. It was used in Maragha observatory also. The instruments were made in the city of Haran.

2. Mount Qasiyun Observatory

Al-Mamun ordered the construction of an observatory at Mount Qasiyun in 830 or 831. Khalid was an important astronomer here who made an observation of a certain star in the constellation Leo in the presence of two scientists Sanad and al-Abbas. Khalid was in fact mutawalli (supervisor) of this observatory (rasad). Ali ibn Isa al-Ustarlabi (d832) was another instrument maker here who wrote a treatise on astrolabe. Al-Mamun died on 10th August

833 (218AH) and all activity came to an end. Ibn Ishaq ibn Kusuf was instrument designer who worked here also. The exact site of this observatory is at Dayr Murran Hill.

Al-Biruni says that a mural quadrant was used at Qasiyun that had an inner radius of five meters, made of marble, and had an accessory part sliding over the arc. This part had a hole through which one looked at the sun. Ali ibn Isa al-Asturlabi (9th century) made divisions of quadrant. He also mentions a gnomon of over five meters consisting of a bar or column of iron standing up vertically.



Mount Qasiyun in Damascus

A. Work performed at observatory

Al-Mamun's astronomers made observations of the sun and moon only, and some investigations of the planets and the fixed stars. A list of star positions was also prepared. The work at Shamasiya and Qasiyun resulted in the discovery of the movement of the solar apogee (farthest point), while their equinox observations led to a pretty exact value of the length of the solar year. (Equinox is when Sun shines down directly on the equator of a planet) The work carried out here covered the following items, length of the solar year, on the obliquity, on the eccentricity of the orbit of the sun, and on the location of the apogee (most distant point from earth in the Moon/ Sun's orbit).

According to mathematician Umar al-Khayyam (1048-1151) the reason for these observations was to establish a solar calendar for Nawruz - new year day of the Persian calendar. The emphasis on the solar and lunar observations was to calculate the eclipses. The measurement of the obliquity of the ecliptic was major item of interest at Shamasiya observatory.

Tables of planetary motions were constructed and presented in a book called *Zij Mumtahan*, (Tested Tables) written by Yahya ibn Abi Mansur (d830). It was also called *Zij Shamasiya*. All of the astronomers of al-Mamun produced a *Zij* (astronomical tables) which is indicative of the fact that it must have been one of the primary objectives for setting up the observatories. Al-Khwarizmi prepared a *Zij* also. Yahya and Sanad were both *munajjim* (astrologers), while al-Abbas was well-versed in geometry, planetary trajectory, and astronomical calculations.

B. Determination of Qibla

One of the important astronomical activities undertaken by order of al-Mamun was the determination of the Qibla. The key to such determination was geographic location of Mecca. Al-Mamun had the latitude and longitude of Mecca determined through observations of lunar eclipses made simultaneously in Baghdad and Mecca. The surveyors measured the distance between these two cities.

A party of astronomers and expert artisans, which included carpenters and brass-smiths, went to Sinjar with instruments to measure the altitude of the sun. Three surveyors Khalid al-Mawrudhi, Ali ibn Isa and Ahmad al Dharra measured the length of a terrestrial degree to ascertain the value of one stadium. The results of this expedition were transmitted by Sanad. Banu Musa brothers of Baghdad, patrons of scholars, paid for the expenses of this adventure. It was thus the first systematic geodetic expedition of its kind. A large map of the world was drawn for the Caliph, who ordered two degrees measurement to be made to determine the size of the earth that came out 20,400 miles and diameter 6,500 miles.

Al-Mamun was conversant with astronomy and had a genuine interest in its problems. Following incident will explain this. In the course of an expedition against Byzantine, al-Mamun noticed that the high mountain by which they were passing had a commanding view of the sea. He ordered Sanad ibn Ali to climb to the top of the hill and measure from it the angle of

depression of the horizon at sunset. This was done and the dimension of the earth calculated from it. Scholar and polymath Al-Biruni says in his book *Qanun al-Masudi* (Canon of Masud- named after his patron Sultan Masud d.1040) that he himself used this method on a hill near Fort Nandana in Pin Dadan Khan, District Jehlum in Pakistan.

C. Banu Musa Brothers

Banu Musa brothers were patrons of scientists and translators. Their yearly income is said to have reached 500,000 dinars. Banu Musa brothers (Muhammad, Ahmad & Hasan) made a series of observations after the demise of al-Mamun. The first two brothers directed the Sinjar and Kufa geodetic measurements. Muhammad died in 259 AH, about 40 years after the death of al-Mamun. Al-Biruni reported their astronomical observations that took place from 858-869. Ibn Yunus mentions six observations, some of them same as al-Biruni. Their fixed stars observations and measurements of the maximum and minimum altitudes of the sun took place in Baghdad from their house by Tigris River close to the city gate Bab al-Taq. They made arrangements for simultaneous observation of a lunar eclipse in Samarra and Nishapur.

The instruments they used included armillary sphere, solstitial and equinoctial armillas in measuring the meridian height of the sun. Habash al-Hasib (864-874) was an outstanding astronomer of al-Mamun. He did observations for ten years and compiled three astronomical tables. He observed the solar eclipse of 829 and determined the time by an altitude of the sun. Muhammad ibn Kathir al-Farghani (805-880) was one of the greatest medieval astronomers employed by Caliph al-Mamun. He composed a book *Kitab fee Harakat al-Samawiya* (Elements of Astronomy) which exerted great influence on European astronomy. This was translated by Gerard of Cremona and first printed in 1493. In 861 he supervised the erection of a Nilometer in Fustat. His several works were distributed in Arabic and Persian and influenced many scientists. Columbus used his calculations for his voyages to America.



Abu Hanifa Dinavari

Abu Hanifa al-Dinavari (815-895) was a Persian polymath, physician and astronomer who lived in Dinavar, (Iran). He authored a book Kitab al-Rasad in which he recorded his observations of the year 235AH (849-850). He made observations from the top of a house in Isfahan. He prepared a Zij and was owner of a private observatory (Sahib al-Rasad) in his hometown.

Muhammad ibn Jabir al-Battani (858-929) is considered the greatest astronomer of Islam. He had a private observatory at al-Raqqah (Syria) where he made his observation for 31 years (887-918). His Zij is called Zij al-Sabi. His tables contain a catalogue of fixed stars for the year 880-881. He determined many astronomical coefficients with great accuracy. He proved the possibility of annular eclipses of the sun. His astronomical tables were edited by Italian scholar C.A. Nallino and published in 1903 in Arabic & Latin.



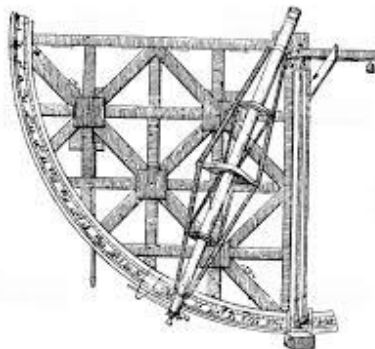
Location of Raqqah

He used the following instruments: 1. Astrolabe 2. Gnomon for precise observations 3. Sun clocks 4. An armillary sphere 5. Parallactic rulers 6. Mural quadrant 7. An alidade. It is assumed that these instruments were of larger dimensions required for the measurements of the obliquity of the ecliptic.

His famous book was Kitab al-Zij, an astronomical treatise with tables, was translated into Latin by Plato of Tivoli, in the 12th century under the title "De Motu Stellarum". First edition of the Zij was published from Nuremberg in 1537 and second edition from Bologna 1645 entitled Die Scientia Stellarum.

He discovered the secular acceleration of the Moon. In 1773 Paris Academy of Sciences awarded a prize to Edmond Halley for giving an explanation of the Moon's secular acceleration by examining solar and lunar eclipse records made by Battani.

Sulaiman ibn Isma made his observations in Balkh, for the determination of the obliquity of the ecliptic in the year 888-890. He used a mural quadrant and an alidade; the side of the quadrant was about four meters. He made some equinox and solstice observations also.



ancient Mural Quadrant

(EQUINOX is the time when night and day are of equal length in all parts of the Earth. The word equinox comes from a Latin word meaning "equal night." Spring equinox: the beginning of spring, often called the vernal equinox. Vernal means "of spring." It occurs on March 20th or 21st. Autumnal equinox: the beginning of autumn. It occurs on September 22nd or 23rd.

SOLSTICE is the time of year when the sun reaches the farthest north or farthest south. The word solstice means "sun stands still." Summer solstice:

The day of the summer solstice is the longest day of the year. It is the beginning of summer, on June 21st or 22nd. Winter solstice: The day of the winter solstice is the shortest day of the year. It is the beginning of winter, on December 21st or 22nd.

Mansur ibn Talha made various observations of the obliquity in Khurasan. Al-Biruni refers to his observations for determining geographical latitudes as well as his eclipse observations for measurements of the longitude. He made comparisons of the longitudes of cities in Khurasan with those of Baghdad and Mecca. He improved the value for the latitude of Mecca found in the time of al-Mamun.

Ibn Amajur: Abu al-Qasim ibn Amajur and his son Abul Hassan Ali were among the greatest astronomers of Islam. Father, son and their emancipated slave Muflih, made extensive observations between 885-933 and produced numerous Zijis; al-Khalis (the Pure), the Girdled (al-muzannar), the Wonderful (al-Badee). Some of their observations are recorded by Ibn Yunis.

They made their observations in Shiraz and Baghdad, which included fixed stars, as well as lunar, solar and planetary observations. His Zij al-Mirrikh (Tables of Mars) are very famous. It is said that they observed the image of the sun in the water. Abul Fazal ibn al-Amid constructed a mural quadrant in Ray, Iran. It was of considerable dimension as the size of the base of the spike at its center is given to be 6 cm. He was a vizier of Buwayhid ruler Rukn al-Dawla (932-976) of Ray.

Abdul Rahman al-Sufi (Dec. 903-25th May 986) was famous for his work on fixed stars. He measured the obliquity of the ecliptic in Shiraz by the order of his friend Buwayhid ruler Adud al-Dawla (936-983) with a ring, whose internal diameter (Qutr) was 2.5 dhira or 125 cm; the smallest subdivision on its scale was 5'. This ring was called Adudi Ring. The measurement of the obliquity was made through observations of the winter & summer solstices in the year 969-970. This was done with a group of scientists like al-Kuhi, al-Sijzi, Nazif al-Yaman (d990) and Ghulam Zuhal.

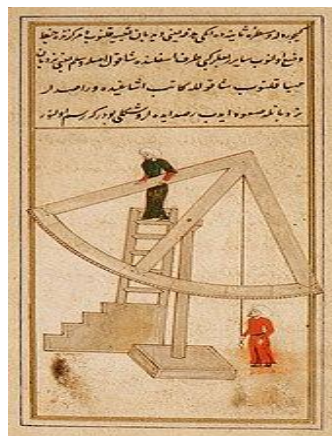


Al-Biruni mentions an observation of vernal equinox and one of autumnal equinox made by al-Sufi in Shiraz. He built a silver astronomical instrument (a celestial globe) for Adud al-Dawla; its weight was three hundred dirhams. Sufi's main work with illustrations is "Book of Fixed Stars" (Kitab al-kawakib al-sabitha al-Musawar) which is considered one of the three masterpieces of Islamic astronomy, the other two being Ibn Yunus and Ulugh Bey. A manuscript is at Bodelian Library, copied by author's son in 1010. Arabic text was published from Hyderabad in 1953. Danish astronomer Hans Schjellerup (1827-1887) translated Book of Fixed Stars into French, St. Petersburg, 1874. Ihsan Hafez earned his Ph.D. degree in 2010 by writing his dissertation: Abd al-Rahman al-Sufi and his book of the fixed stars: a journey of re-discovery. James Cook University, Australia/Singapore.

Ibn al-Alam (d985) prepared a Zij and conducted most of his observations in Baghdad. The positions of Mars are more accurate in his Zij than in any other, his Zij received much favor during the next two centuries. Al-Tusi found his astronomical observations more reliable than those of Maragha observatory. He found the obliquity of the ecliptic to be 23 degrees, 34' 2". It is said that he made his observations from a private observatory in Baghdad.

Abul Wafa al-Buzjani (940-997) was a distinguished mathematician and astronomer. He states in his al-Majisti that he made many observations for the determination of the obliquity of the ecliptic. They were made at Bab al-Tibn in Baghdad. Al-Biruni was apparently in contact with Abul Wafa for they made arrangements to observe the lunar eclipse of 997 and compare notes.

Abul Wafa observed it in Baghdad while al-Biruni in Khwarazm. The difference in local time was found to be one hour. In an observation of 995 he used a 21-foot, 8-inch quadrant. It is possible that he had fixed instruments. His Zij is called al-Zij al Wadih. Khawrizmi developed a sinical quadrant (Rubu al-Mujayab) In 9th century Baghdad that was prevalent until the 19th century.



Quadrant in a Turkish illustration

3. Sharaf al-Dawla Observatory

Sharf al-Dawla son of Adud al-Dawla (r982-989) built an observatory in the garden of his palace in Baghdad. He ordered the observations of the seven planets in 378 AH (June 988) and al-Kuhi was vested with this work. A building (bayt) was constructed for this purpose in his garden. It had a director (Sahib), and its mandate included observations of seven planets. Abu Sahl Al-Kuhi, leader of the astronomers, designed the instruments for this Bayt al-Rasad.

The observations were made in the presence of judges, scientists, and scholars like the judge ibn Bilal, al-Kuhi, al-Buzjani, al-Saighani, al-Samri and al-Maghribi. Abu Hameed Al-Saighani (d990) was an inventor and instrument maker, who constructed instruments for this observatory.

Al-Biruni says that al-Kuhi (d1000) constructed in Baghdad a building whose floor was in the form of a section of a sphere with a radius of 12.5 meters. The center of this sphere was located at the hole at the top of the

building; solar rays entered from this aperture and traced the daily trajectories. One solstice observation was also made.

This observatory was different from al-Mamun's observatories, in that it had a director and its program of observations was certainly substantial.

Abu Mahmud Al Khujandi (d1000) made an important measurement of the obliquity of the ecliptic in the city of Ray in the year 994. The instrument constructed for this purpose surpassed all previous ones in size; it consisted of a sixty-degree meridian arc and was called al Suds al-Fakhri (named after his parton Fakhar al-Dawla). Suds mean the sixth part (of a circle). It had a radius of about 20 meters. This was al-Khudanji's invention, with this instrument degrees, minutes and seconds could be read. Each degree was subdivided into 360 equal parts, and each ten-second portion was distinguished on the scale. The arc, which was constructed between two walls, was faced with wood, and on this wooden surface were sheets of copper. The hole on top of the arched ceiling of the instrument had a diameter of about 2cm. The measurement took place at Jabal Tabruk, near Ray, Iran. He had many outstanding astronomers of his time assisting him in this work. The second solstice observation was made in 997.

D. Observatory as a royal Institution

By the end of tenth century observatory was a specialized institution with fixed locations. They were devoted to the research in astronomy. It contained many instruments and scientific staff. There was an emphasis on building large-scale instruments. Administratively it was well organized. It also had a director and was given some kind of legal status. The program of work included observations of the planets, as well as those of sun and moon, and the compilation of new astronomical tables. An institution of this magnitude could not function without royal patronage; hence observatory was a royal institution. Other observatories built alongside Sharf al-Dawla were Adud al-Dawla in Shiraz and Fakr al-Dawla in Ray, Iran.

Maslama al-Majriti (d1007 Madrid) was a renowned mathematician and astronomer of Islamic Spain. He edited and corrected the astronomical tables of al-Khawrizmi, translated into Latin by Adelard of Bath in 1126. He wrote a treatise on the astrolabe that was translated by John of Seville. Michael Scot translated his book on astronomy Kitab al-Hay'ah.

Maslama created a school of astronomers consisting of his students (like al-Karmani, and ibn-Samh), and their students marking the beginning of science as an organized activity in Islamic Spain. All his students commented on the use of astrolabe, and Zij al-Sindhind.

Ibn Samh (29th May 1035) was a famous Hispano-Muslim mathematician and astronomer. He wrote two treatises on astrolabe, its use and construction. His Zij (astronomical tables) was as good as his master Maslama al-Majriti. Ibn al-Saffar (d1035) was a mathematician and astronomer who compiled astronomical tables according to the Siddhanta method. Plato of Tivoli translated his treatise on the use of astrolabe, Kitab al-Amal bil Asturlab, into Latin.

E. Abu Rehan Al-Biruni (15th Sep. 973- 1048)

Al-Biruni was a contemporary of Ibn Sena, they exchanged letters on scientific questions. Al-Biruni built several observational posts for the measurement of the obliquity of the ecliptic as well as determination of geographical locations. The earliest observation he made in 990 was in Khawarizm when he was a youth. He repeated measurements of latitude in several cities of Khurasan, using instruments of varying sizes. He used a ring with a diameter of 7.5 meters, a quadrant with a radius of 3 meters, and in a village near Kabul, an improvised instrument consisting of a drawing made on the back of a calculating board.



He composed an astronomical encyclopedia (Qanun al-Masudi fee Haye wal Najum) which contains a collection of 23 observations of equinoxes beginning with Ptolemy, and ending with observations he made himself. While living in Ghazna (Afghanistan) he wrote a general treatise on mathematics and astronomy, entitled al-Tafheem le-Awaile Sinaat al-Tanjeem (Book of Instruction in the elements of art of Astrology), translated into English by Ramsay Wright, Professor of Biology, University of Toronto and published from London in 1935. A manuscript of this book is available at the British Museum No. OR8349.

Al-Biruni went through many ordeals while doing investigations of the latitude; so much so that he compared this to ordeals of Noah and Lot, and prayed that he may follow them in rank in meriting Allah's mercy. The knowledge of geographical locations of cities was important to determine the direction of Qibla and also for revisions of astronomical tables. He mentioned values of longitude and latitude of Mecca with fractions smaller than a degree. To obtain this he used sizeable instruments. Astronomical tables had another utility, i.e., determination of beginning and end of Ramadhan, though actual observation of the new moon was equally important. This indicates that religious needs promoted the study of astronomy in Islamic countries.

A book Rasail al-Biruni containing four of his mathematical and astronomical treatises was published from Hyderabad in 1948, while another volume entitled Rasail abi Nasr ila al-Biruni included 15 treatises on mathematics and astronomy. A drawing made by him of an astrolabe with

gears was forerunner of the mechanical clock. He wrote a treatise on making astrolabe fee instiab al-wujuh al-mumkina fee sinaat al-Usturlab.

His writings indicate that he accepted the possibility that Sun, not the Earth was the center of the solar system. He suggested that earth revolved around the Sun and on its axis, & the axis is tilted. . He calculated the circumference of the earth 24757.92 miles while the current figure is 24873.75 miles. He calculated the radius of the earth 3938.75 miles while the current figure is 3958.78 miles. These dimensions were obtained 700 years before French scientist Picard revised them. Will Durant says – “Al-Biruni took it for granted that earth is round; noted the attraction of all things toward the center of the earth. Earth turns daily on its axis and annually around the sun.” An observatory was built in 1976 in Shiraz as a tribute to his scientific genius - Abu Rehan Al-Birooni Observatory - Shiraz University.

4. Cairo Observatory

Abul Hassan Ali Ibn Yunus, (950-1009) one of the greatest Muslim astronomers, author of Hakimi Tables, was a resident of Cairo, where Fatimid caliph al-Hakim bi-Amrillah (996-1021) built an observatory for him. It was located on Mount Muqattam, near Cairo and was part of the Darul Hikma (Hall of Science- operational 1005- 1171) founded by al-Hakim. Cairo observatory (Rasad al-Hakimi) which was part of the Hall of Science, was one of the most famous in the history of Islam. Names of astronomers who worked here are recorded in history.



It is said that the observatory ceased operation after the death of Ibn Yunus. A copper instrument resembling an astrolabe and resting on two pillars was used for making observations. It contained twelve signs of zodiac; it was three spans in length. Ibn Khaldun (1332-1406) says that al-Hakim was guided by astrology in his decision making of state affairs. He used to ride his donkey and go to Mount Muqattam for praying, and according to some, for spiritual contact with the stars.

Al-Hakim's treatment of famous scientist, physicist, and astronomer, ibn al-Haitham (965-1039) and his court physician Ali Ibn Ridwan (d1061) indicated he was unpredictable. Ibn al-Haitham's book *Fee Hayat al-Alam* (on the configuration of the world) in this respect is worth mentioning.

Zij al-Hakimi al-Kabir, were totally reliable, and based on painstaking observations. French historian of astronomy Jean Baptiste Delambre (1749-1822) noted in his 1819 translation of the Hakemite tables that two of Ibn Yunus' methods for determining the time from solar or stellar altitude were equivalent to the trigonometric identity identified in Johannes Werner's 16th-century manuscript on conic sections. Now recognized as one of Werner's formulas it was essential for the development of logarithms. Ibn Yunus's observations on conjunctions and eclipses were used in Dunthorne and Simon Newcombs respective calculations of the secular acceleration of the moon.

He observed one solar and three lunar eclipses from the mosque of Abu Jafar al-Maghribi. One observation he made from his grandfather's house, and still another from the roof of the old mosque, Al-Jami al-Atiq in Cairo. His house was in the Fustat quarter of old Cairo, to the west of Qarafa. He determined the latitude of this place many times. He is said to have used portable instruments. In one instance he used an instrument in measuring the obliquity of the ecliptic, belonging to al-Aziz, father of al-Hakim.

His astronomical tables contained observations of eclipses and improved the values of astronomical constants. His tables were printed in

Arabic along with French translation. He solved many problems of spherical astronomy.

According to C.A. Nallino (1872-1938), the Italian orientalist, Ibn Yunus started his observations in 977, and finished them in 1007. He believed in astrology also, seven days before his death he predicted his own death, prepared his tomb, and destroyed the first drafts of his manuscripts by throwing them into water.

Ibn al-Saffar flourished in Cordova, capital of Islamic Spain and died Denia in 1035. He was a noted mathematician and astronomer who wrote a treatise on astrolabe *Kitab al-Amal bil Asturlab* (Use of the astrolabe) that was translated into Latin by Plato of Tavoli. He also compiled astronomical tables.

Kushyar Ibn Labban (971-1029) lived in Jilan, Iran. His main work was compilation of astronomical tables, *al Zij al-Jami wal-Baligh* (comprehensive and mature tables) that was translated into Persian.

5. Hamadan Observatory

Abu Ali Husain ibn Sena (980-1037) convinced Ala al-Dawla, Ameer of Hamadan, that there were deficiencies in the ephemerides (*Taqweem*) based on old observations. The Ameer agreed with Ibn Sena to build an observatory in Hamadan in 1023 for observations of the planets (*Kawakib*). Ibn Sena assigned his pupil and biographer al-Juzjani to prepare necessary equipment and employ instrument makers. Some of the instruments he invented himself, and composed technical manuals on their use. Ibn Sena spent eight year making observations.



It is said that measurements of azimuths (angular distance east to west from the North point) and altitudes (up and down) were carried out with a certain device that embodied the principles of micrometer. This was installed in the newly built observatory. The diameter of the azimuthal ring was over seven meters. No details are available on the work carried out here, like astronomical tables. George Sarton has described Ibn Sena as, "the most famous scientist of Islam, & one of the most famous of all races, places and times. " He devised an instrument whose purpose was similar to that of the Vernier i.e., to increase the precision of instrument readings. He observed Venus with naked eye.

6. Malik Shah Observatory

This was the first Islamic observatory that functioned as an institution for 20 years. Malik Shah was the Saljuq Sultan (r1072-1092) who founded this observatory in the eleventh century. Madrasa system was established during his reign by his vizier Nizam al-Mulk. A group of outstanding astronomers, Umar al-Khayam, al-Asfizari, and ibn Naneeb were invited for its foundation. It functioned until Sultan's death. The construction work was supervised by Muhammad al-Bayhaqi, while al-Mamuri was assigned to make instruments. There were eight astronomers (ashab ar-Rasad) employed by this institution.

Umar Khayam produced al-Zij Malikshah probably during the operation of this observatory. It survived its founder for only a short while. Umar Khayyam (1048-1123) was one of the greatest mathematicians of mediaeval times who was also an eminent astronomer and poet. In 1074-75 Jalal al-Din Malikshah called him to the new observatory of Isfahan to reform the old Persian calendar. His calendar was called al-Tarikh al-Jalali, its era was 16th March 1079. The calendar is very accurate, more accurate than the Gregorian calendar.

7. Al-Afzal Observatory

It took five years to build this observatory in Cairo 1120-25. Solar observations were made here. Tenth Fatimid Caliph al-Amir bi-Ahkam Allah

(1096-1130) was ruler of Egypt at that time. Two of his viziers took personal interest in its foundation, al-Afzal al-Jamali, and al Mamun al-Batai'hi. Among the famous astronomers who worked here were ibn al-Halabi, ibn al-Hayshami, and Sahlun who received monthly allowances from the Caliph. Their work involved making a yearly ephemeris (Taqweem) for the year 513 AH (1119-1120) and compare them with others.

Among the instruments used was a ring of about five meters diameter, and an alidade made of copper. Ibn Qaraqa was responsible for making instruments. An armillary sphere of a diameter of about 2.5 meters was also constructed. All work came to an end upon the death of al-Bataihi in 1125. It should be noted that taqweem contains for a whole year the daily positions of the planets, their conjunctions and oppositions, and information on solar & lunar eclipses. The observatory was also called Observatory Mosque (Masjid al Rasad al Juyushi) as it was later housed in a mosque. The observatory was demolished due to personal jealousies.



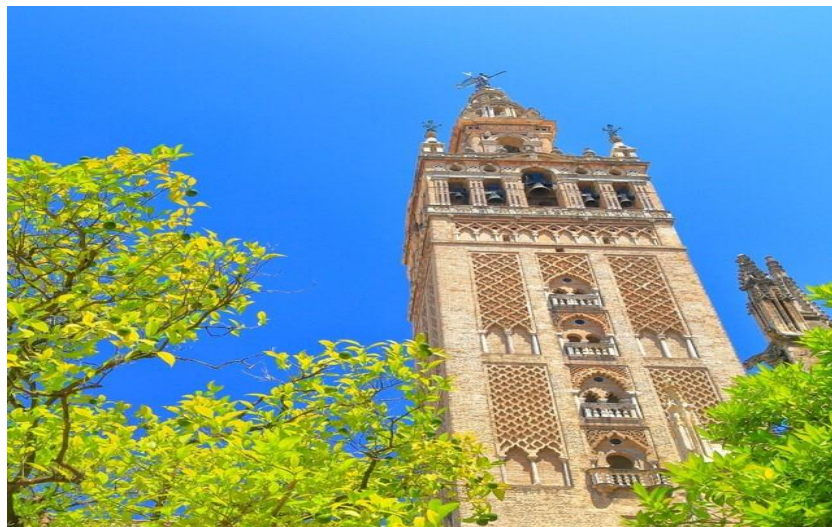
Alidade

Badi al-Zaman al-Usturlabi was a famous scientist and instrument maker. His Zij al-Mahmudi was devoted to Saljuq Sultan Mahmud (d1131). Abd al- Rahman al-Khazini was the author of al-Zij al Sanjari, prepared for Sultan Sanjar (d1157), tables giving positions of the stars for the year 1135-36. He observed and calculated positions for all planets as well as sun and the moon at conjunctions and eclipses. He found disagreements for all of them. He was in possession of good instruments so he could measure the obliquity of

the ecliptic in Isfahan. He composed a book on making astronomical instruments.

8. Giralda Tower of Seville, (Spain) Observatory

It is said that famous Spanish astronomer Jabir ibn Aflah (1100-1150) used the minaret of the Jami Mosque in Seville for making observations. This was in fact first observatory in Europe. Overlooking the city of Seville, it is now called Giralda Tower, and visited by millions including this author in 1999. The construction of the minaret of the mosque started in 1172 and completed in 1197.



There is an inscription on the wall in Arabic at the beginning of the ramp (there are no stairs), giving brief history of the tower. The tallest point of the tower is closed to the visitors, but one can go around the enclosed balcony to observe the sky clearly.

Jabir criticized Ptolemy violently in his work *Islah al-Majisti* (corrections of *Almajest*) on many astronomical matters. Jābir made a substantial change to Ptolemy's account in that he placed the orbits of Venus and Mercury, the minor planets, outside that of the Sun, rather than between the Moon and the Sun as had been the case in *Almajest*. His book *Kitab al-Hay'a* (Book of Astronomy) was translated by Michael Scot (d1235) as *De Astronomica Libri IX*, printed in Nuremberg in 1534.

Regiomontanus in his work *On Triangles* (c.1463) copied much of the work on spherical trigonometry without giving any credit to Jabir, as reported by Gerolamo Cardano in the 16th century. Jabir invented an instrument as the Torquetum a mechanical device to transform between spherical coordinate systems. A Jewish scholar from Marseille Samuel ben Juda translated a treatise written by Abu Abdullah Muhamad ibn Muaz of Seville on the total solar eclipse that occurred in 1079.

Qazi Sa-id al-Andalusi (1029-16th June 1070) was a historian of science and an astronomer who flourished in Toledo. He was a great observer, observations made by him and his fellow astronomers were very valuable to al-Zarqali. He wrote in 1067 a summary of universal history *Tabaqat al-Umam* (Categories of Nations) with special attention to history of science.

Abu Ibrahim Al-Zarqali al-Naqqash (1029-1087), Spanish astronomer, and instrument maker lived in Cordoba. He was the best observer of his time, who made his observations in Toledo in 1061 and 1080. His influence on medieval European astronomers was considerable; his Toledan tables formed the basis of later works. These tables were mainly based on his own observations, but also upon those directed by Qadi Saeed al-Andulasi. Many Muslim and Jewish astronomers also participated in their preparation.

Al-Zarqali (Arzachel) was an illiterate coppersmith who was employed by astronomers to make instruments. He was so successful in his art that he started studying astronomy. Soon he became prominent member of the group of scientists engaged in preparing Toledan Tables.

He invented an improved astrolabe called SAFIHA that is a universal instrument making possible observations and reductions in regard to planets. He was the first to prove explicitly the motion of the solar apogee with reference to the stars; according to his measurements it amounted to 12.04" per year (the real value being 11,8"). Samuel ben Juda translated Zarqali's treatise on the movement of fixed stars. Another Spanish Jew translated into Spanish ibn Abi Rijal's treatise *Kitab al-Bari* (The functions of the stars).

Ibn Bajja (d1139 Avempace) made an observation from the roof of his house and saw two black spots on the surface of the sun. His calculations corresponded with those of Mercury and Venus, he concluded that these two spots must be these two planets. In the 13th century, Qutab al-Din Shirazi identified this observation as the transit of Venus and Mercury. Though he was not a professional astronomer, it appears that his housetop was equipped with certain instruments to make observations. Sooted glass may have been used to look at the sun.

9. Morocco (Fas) Observatory

The observatory in the city of Fas, near Morocco, was called Burj al-Kawakib (Tower of Stars). The purpose of its foundation in the twelfth century was observations of the new moon. It remained operational for several centuries.

Noor al-Din Ishaq al-Bitruji (d1204- Latin Alpetragius) was born in Morocco, but lived mostly in Seville. He did not trust the human senses given the distance between the observer and the spheres. His magnum opus Kitab al-Hay'a (Book of Form, or Spiral motions of the Heavenly Bodies), was translated by Michael Scot into Latin, *De Motibus Celorum Circularibus* in 1217 in Toledo, reprinted from Berkley, USA in 1952. He was the first astronomer to present a non-Ptolemaic astronomical system as an alternative to Ptolemy's models.

His astronomical system exerted a deep influence on European scholars up to the time of Copernicus who cited his system in his book *De Revolutionibus*. Roger Bacon (1220-1292) expounded his system in detail discussing his theory of tides in his work *Opus Majus* (1267), while Grosseteste (d.1253) plagiarized his work. The English translation of his work with Arabic text was edited by Goldstein entitled *al-Bitruji- On Principles of Astronomy*.

10. Maragha Observatory

When Mongol ruler Hulagu Khan captured Alamut (Syria), in 1256, many astronomical instruments were found in the mountain fort. Among these were,

a celestial globe (dhat al kursi), armillary sphere, complete (tam), a half astrolabe (nisfi), a parallactic ruler, and Shua. Nasir al-Din al-Tusi (1201-74) is reported to have worked there.

Maragha was one of the most famous Islamic observatories built in the 13th century in Maragha (Azerbaijan), NW of modern Iran. Its foundations were excavated by Russian archaeologists. Al-Tusi suggested to Helagu Khan to build this observatory, and construction work started on a hill in the month of Jumadi al-Ula 657 (April 1259). The flattened top of the hill is about 400 meters in length and 150 meters in width. Drinking water was raised to the top of the hill with special devices and water wheels constructed by al-Urdi. A mosque and Helagu's residence on the top of the hill was also built by Muayya al-din al-Urdi (1200-1266).

The main building of the observatory was a marvel and ' a treat to the eye'. The building had a dome, its library containing some 400,000 volumes. There was a hole on the top of the dome through which sunrays entered. The image thus formed served for the measurement of the mean motion of the sun in degrees, and in minutes. Various times of the day were also determined in such a way.

It employed a staff of twenty astronomers, one Chinese, it was supported by a library , workshop for storing and constructing and repairing instruments. One of its famous was scientist was Muayya al-Din Al-Urdi's whose observational devices and those of Tycho Brahe have striking similarities.

There were representations of celestial spheres, illustrations of the phases of the moon and signs of the zodiac. There were also terrestrial and celestial globes, maps of seven climes, and illustrations regarding the length of the days and nights.



Maragha Observatory site with protective dome- housing remains of main building.

A terrestrial globe was made of pulp paper (or cardboard). A metallic celestial globe constructed in 1279 by Muhammad ibn al-Urdi (son of Muayyad al-din) is still preserved in a Dresden, Germany museum, Germany. The armillary sphere was fixed on the ground; traces of the places where instruments were placed can still be seen today. Many instruments were constructed in 1261.

Al-Urdi has given a detailed account of the instruments, which included 1. mural quadrant, 2. armillary sphere with five rings and an alidade 3. a solstitial armilla, 4. an equinoctial armilla 5. azimuth ring with two quadrants equipped with alidades for the measurements of angles of elevation 6. parallactic ruler 7. An instrument for the determination of the azimuths 8. sine and versed sine instruments 9. the perfect instrument (al Ala al-Kamila) 10. models of instruments prepared by al -Urdi.

Nasir al-Din al-Tusi (d1274) was director of this observatory. Helagu Khan never took a trip without consulting him. The main achievement of this observatory was the Ilkhani Zij completed in 1271. A copy of these astronomical tables exists in Bibliotheque Nationale in Paris (MS No. 779).

There were 15 astronomers employed here. Among the many leading astronomers following are worthy of note: Ali ibn Umar al-Qazwini, al-Urdi, al-Akhlati, al-Maraghi, al-Maghribi, Qutub al-Din al-Shirazi, Shamsuddin al-Shirwani, Najmuddin al-Qazwini, Al-Fuwati, the librarian. The revenues for the

operation of this observatory were provided from the Waqf (Islamic charitable endowments). It is said that twenty thousand dinars were spent on instruments. Al-Kashi has mentioned the 'geometrical pulpit' which stood in the midst of the main building. " The principal achievement of this observatory was the issue of a revised set of astronomical tables for computing the motions of the planets, together with a new a star catalogue."

The observatory continued its operations under seven Ilkhani rulers. One of the rulers appointed Asil al-Din (d.1306) son of Nasir Al-Din its director. It ceased operation under Uljaytu Khan in 1316. Qutub al-Din Shirazi was one of the esteemed scientists who survived al-Tusi by about 35 years. He prepared a map of the Mediterranean in 1290 and presented to Ilkhan ruler Arghun Khan.

11. Tabriz Observatory

The Ilkhanid ruler Ghazan Khan (1295-1304) built a mausoleum for himself along with other buildings consisting of a mosque, a monastery, two madrasas, a hospice for sayyids, an observatory, a hospital, a library, a house of law, a place of ablutions, a bath house, and a primary school. This complex was called Abwab al-Birr al-Sham as they were located in the suburb of Sham in Tabriz, Iran. The foundation was richly endowed and Waqf revenues were provided for its maintenance. A clock of great complexity was built for the observatory. Ghazan Khan had a very good knowledge of medicine besides astronomy. He visited Maragha observatory many times.

The construction work completed in 1304, it remained operational for 15 years. The observatory provided salaries for a mudarris (professor) and a mueed (assistant), as well as for a treasurer. It said that Ghazan Khan prepared a new calendar as he decided to unify different calendars. The Khani solar calendar was adopted in 1302.

12. Samarqand Observatory

Samarqand (Uzbekistan) was an important cultural center during the reign of Sultan Timur (1369-1405) who built an observatory in this city in 1402.

During the reign of Timur's grandson Muhammad Turgay Ulugh Beg (1394-1449) the scientific activity in the city reached at its zenith. Prince Ulugh Beg, himself a talented astronomer, enjoyed very much to indulge in mathematical and astronomical matters. Al-Khashi, Qazi-zadeh al-Rumi and Ali Qushji (d1474) were leading astronomers at this institution.



Ulugh Beg observatory walls lined with marble

Ulugh Beg took part in all the scientific meetings that took place in his palace, before the construction of the observatory. The astronomical tables prepared by him in 1437 are called *Zij al-Gurgani*. These were published in Persian and Latin in 1650 by John Greaves, while French historian of science Louis-Pierre-Eugène Amélie Sédillot (1808-1875) translated them into French in 1844, Paris.

Al-Birjandi (d1528) composed *Sharh Zij Ulugh Beyk*, a commentary on the astronomical tables of Ulugh Bey. He also wrote a book on instrument making (*Risala fee Alate Rasad*) a manuscript preserved in Raza Library, Rampur, India. Instruments for this observatory were made by Jalal al- Din al-Usturlabi. A copy of Ghiys al-Din Al-Kashi's book *Miftahul Hisab*, in his own handwriting, is preserved at Nur Osmania Library, Turkey. Al-Kashi (1380-1429) says in the introduction to his book that he wrote this book for Bey's library attached to the observatory.



Ulugh Beg was himself director (Sahib ar-Rasad) of this observatory; he made observations of the fixed stars for eight years 1430-1437. It remained operational for thirty years. The monumental size of the round building and its huge meridian arc made of masonry are a living testimony to its founder. The radius of the arc was equal to the height of the dome of the magnificent Ayasofya Mosque in Istanbul. There were beautiful models (nuqushi dilpuzeer) of ten celestial spheres, the seven planets, and the fixed stars. There was a terrestrial globe divided into climes, mountains, seas and deserts.

In 1908 Russian scientist Vjatkin unearthed the underground remains of the meridian arc which was the major instrument of the observatory. The main observatory building was on the top of an 85-meter mountain, and the height of the building was about 30 meters. The building was demolished 50 years after Beg's death, mainly to make use of the marble. It is stated in some sources that the obliquity of the ecliptic was measured here with the help of Sudsi Fakhri.



Jantar Mantar observatory in New Delhi built in 1724 by Raja Jai Singh. Author of this article visited this observatory in 2009.

Raja Jai Singh (1681-1743) of India prepared astronomical tables *Zij Muhammad Shahi Hindi*, which were dedicated to Sultan Muhammad Shah (1719-1748). In the introduction to the tables Jai Singh speaks of “instruments such as those which were constructed in Samarkand”. They are armillary sphere, parallactic ruler, the *sudsi Fakhri*, and the *al-Ala al-Shamila*. Al-Kashi has mentioned in his *Khaqani Zij* that a mural quadrant (*libna*), a sun clock on the palace wall, water clocks, an astrolabe of one *dhira* diameter, was also used here.

13. Istanbul Observatory

This observatory was founded at the suggestion of Egyptian Taqi al-Din Ibn Maruf to Sultan Murad III (1574-1595). The construction work completed in 1577, the year the famous comet appeared on the skies. Taqi al-Din was the director of the observatory. The design of the main building was elaborate, with residence for the astronomers, administrative offices, and a library. There was a deep well or a tower for the daytime observation of the stars. Unfortunately, the building was demolished in 1580 on advice received by Sultan Murad from religious leader Shayk al-Islam Qazidada.

Taqi al-Din is reported to have measured the latitudes, and longitudes of all parts of the earth. Some of the instruments (compasses & rulers) used were of a portable kind. There were 15 astronomers on its scientific staff. Other instruments used were armillary sphere, mural quadrant, parallactic ruler, ruler quadrant, instrument with two holes for the measurement of apparent diameters and eclipses, instrument with cords for the determination of equinoxes (invented by Taqi al-Din), *Mushabaha bil manatiq* (invented by the director), a mechanical clock with a train of cog wheels, and a *sunaydi ruler*.



astronomers at work at Istanbul observatory

Astronomical tables of Ulugh Bey were revised here. These instruments are similar to those used by Tycho Brahe (1546-1601) in his observatory in Denmark. A terrestrial globe made here in the sixteenth century shows southern hemisphere of Europe. Religious fanaticism was the main reason for the demolition of this state institution.

Following the Islamic tradition, Maharajah Sawai Jai Singh (1686-1743) built observatories in several Indian cities, Dehli, Jaipur, Banares, Mathura, Ujjain, between 1728 and 1734. Instruments in these observatories were made of stone and lime, as brass instruments could not be large enough to indicate the minutes. Jai Singh made observation for seven years and made a star catalogue. He also prepared astronomical tables *Zij Muhammad Shahi*, for his patron Sultan Muhammad Shah.

F. Summary

In all the observatories mentioned here, many things were strikingly similar. For instance astronomical tables were prepared, larger mosques were used for astronomical observations, large instruments were used for which large buildings were constructed. These observatories were state institutions patronized by Kings, Sultans, and Ameers. There were huge libraries attached to the observatories with useful books on mathematics, algebra, medicine, geometry, and astronomy. People of various professions cooperated in its planning, and construction like engineers, masons, architects, mechanics,

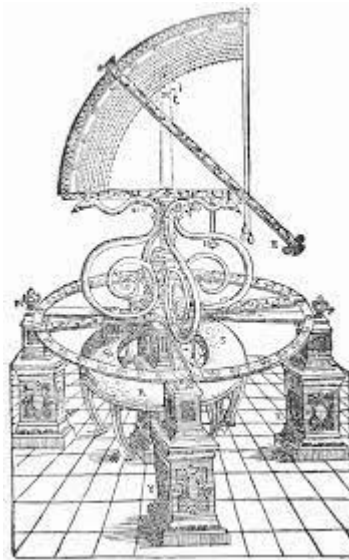
apprentices and instrument makers. The administrative staff included treasurers, librarians, and clerks. These observatories were places where scientific ideas were exchanged, discussions held and revised theories created. Mathematical sciences and astronomy was taught to budding scientists.

Astronomers of Islam sought to increase the sensitivity of the instruments and to render possible the detection and reading of increasingly smaller fractions of a degree by augmenting the size of the instruments. The meridian arcs of al-Khudanji and Ulugh Bey can be cited in this connection. Masonry quadrants of large size were used, and even a combination of a horizontal circle with two revolving quadrants mounted upon it, foreshadowing the modern theodolite. (Hist of Science by Sedgwick, page 190, 1939 NY).

The main work done in these observatories was of course preparing astronomical tables based on fresh observations, but planetary motions and trajectories were also studied. Calendars were revised, & times figured out for religious festivals. At the Qasiyun observatory daily observations of the sun and moon were made for a whole year, while Jabir ibn Aflah also speaks of daily observations of the sun in Spain.

G. Islamic Influence on Europe

Modeled after the Islamic observatories, many observatories sprang up in European cities like Paris (1666), Greenwich (1675), Leiden (1632), and Copenhagen (1637). Prior to these Tycho Brahe had built two observatories on the Island of Hveen in Denmark. The Kassel observatory (1561) of Wilhelm IV of Hesse (1532-1592) was the first European observatory comparable to Islamic ones. An armillary sphere from this institution is preserved in Marburg. Wilhelm IV observed a comet in 1558 with a torquetum (turketum). He also used an azimuthal quadrant, which was one of the standard instruments in Islamic observatories.



Tycho's Brass azimuthal quadrant

Greenwich observatory was equipped with a sextant of seven feet radius and two pendulum clocks supplied by John Flamsteed. In addition, there was a three feet quadrant and two telescopes. The Paris observatory had a deep well that was used for daytime observations. There was also a quadrant of nine feet radius and a six feet sextant. A private observatory was built in Danzig (Poland) by Hevelius in 1639. Most of these observatories were connected to universities in those cities.

Astronomical tables were made or old ones revised in these institutions; for instance, Tycho Brahe's tables were revised in Greenwich. Copernicus is reported to have used three instruments, a quadrant placed in the meridian, a wooden parallactic ruler, and an armillary sphere with six rings. The parallactic ruler could be revolved around a vertical axis; such a revolving ruler was among the instruments designed for the Maragha Observatory. Al-Kashi has mentioned this ruler and this was used by Tycho Brahe also, who used many Islamic instruments of great size like mural quadrant, a wooden quadrant, brass azimuth quadrant, armillary sphere, & the parallactic ruler in his observatories in Uraniborg (1575), and Stjerneborg (1584). After 21 years work could not carry on, as his patron was Frederick II, King of Denmark died. Later on these observatories were moved to Prague and

Benatky, where his patron was Rudolph II Emperor of Germany. The Samarqand observatory had a staircase, Brahe's observatory also had a staircase. There was a chemical laboratory in Maragha observatory, so did Brahe's. Alfonso X, King of Spain, also prepared astronomical tables, but there is no evidence to prove he had an observatory.

H. Islamic influence on Renaissance

It is a fact that Islamic scientific influences played a great part in the renaissance of the 12th century through translations of Arabic books and scientific treatises. In the fifteenth century it was Germany that came into close contact with learning of Islam, specifically the Ottoman Empire. The Ottomans learned how to make canons from Europe, and the map of America by Piri Reis, an admiral of Sulayman the Magnificent.

Elements of Euclid, written by Khawaja Nasir al- Din al-Tusi, was published in Arabic in Rome at the end of 16th century. In the middle of 17th century, al-Tusi's ideas on Euclidean postulates became available in Latin translations that influenced the work of Girolamo Saccheri in the 18th century. There is a striking resemblance in the trigonometries of al-Tusi and German astronomer (Johann Muller) Regiomontanus (1436-76).

Historians have pointed out that the mathematical devices created by the Maragha scientist's re-appeared two hundred years later in the work of Copernicus. In particular his model of the moon and mercury have been found to be identical with those of Ibn Shatir. Then lunar theory of Ibn al-Shatir was identical to that of Copernicus except for trivial differences in parameters. According to E.S. Kennedy " the universes of these two individuals are geocentric and heliocentric respectively." It is said that Copernicus used a cinematic device thought out by al-Tusi. The instrument torquetum (the Turkish instrument) was also widely used in Europe. Qutb al-Din Shirazi stated that Mercury had the same characteristics as Venus, later on the same thing was stated by Regiomontanus.

Muslim astronomers have left on the sky traces of their knowledge, which can be seen in the names of various stars. Acerb (scorpion), Algedi (kid), Altair (flyer), Deneb (tail), Pherkad (calf). Consider the following names of stars also: Albireo (orange star in constellation Cygnus), Alcaid (blue-white star), Alcor (white star), Alcyone (double star), Aldebaran (red star in constellation Taurus . Arabic al-dabaran meaning follower, ie Pleidas), Algenib (in constellation Pegasus), Algol (in constellation Perseus), Alhena, Algeiba, and Altair (bright star in constellation Aquila), Al-mucantar (an instrument for measuring altitude and azimuth). Then there are technical terms that are Arabic in origin as azimuth (Arabic al-Sumut – the ways), nadir and zenith (Arabic al-Samt), Alidade (Arabic al-idadah – moving radius) , Almanac (Arabic al-Manakh)

Two surface areas of the Moon in the Sea of Nectar are named after Albategnius (Al-Battani), and Abulfeda , while a surface area in the Sea of Clouds is called Arzachel (al-Zarqali).

In conclusion we must state that Islamic countries were indeed the birthplace of observatories. Early European observatories grew out of the observatories of medieval Islam.

I. 20th century Observatories

Now we give details of the famous observatories of 20th century. One thing common between these modern observatories with Islamic observatories is that both had domed buildings on high mountains and functioned under a director.

Anglo Australian Telescope: (AAT) is a 153-inch reflector telescope completed in 1965. It is considered among the world's best. Though not located at a high altitude, the seeing conditions are good.

William Herschel Telescope: It has a 165" mirror. It is located on the summit of Los Muchachos, an extinct volcano in the Canary Islands (near Spain) at an altitude of 7648 feet. The Isaac Newton Telescope was also on this mountain with 101" mirror, later on transferred to La Palma in 1983.

Palomar Reflector in California: Located at Palomar Mountain it has a 200" reflector. The Hale reflector was brought into action in 1948, and was at one time the world's largest observatory. It is now used with electronic equipment. It also has a 48-inch Schmidt telescope.

Mauna Kea in Hawii: Mauna Kea is an extinct volcano over 14000 feet high. On its summit several large telescopes have been erected and more are planned. The main advantage is the thinness of air. Modern observatories are built at high altitudes, where air is thin and dry. Kieckhefer telescope used here has a 387" mirror made from 36 hexagonal segments. This is the largest optical telescope now in use that was completed in 1992. UK infrared telescope is operational here mainly to collect infrared radiation.

Mount Wilson Observatory: It has a 100" reflector telescope. It was mothballed in 1980's because of light of Los Angeles. Hooker telescope is used here; it became operational in 1917.

Mount Pastokhov: It started its operation in 1975 and has the world's largest single mirror telescope (236") built by the Russians. The altitude is 6600 feet but conditions are not very good.

Atacama Desert in Chile. There are at present three observatories. (1) La Silla with 138" mirror started work in 1977 run by European Southern Observatory. (2) Cerro Tololo started its operation in 1976 and (3) and Las Campanas is a 100" telescope that became operational in 1976 and is run by the US. These observatories have the advantage of being able to study some of the most interesting regions of the sky that are inaccessible from the US or Europe.

Polar Observatory: It is located in the South Pole, where viewing conditions are excellent though the climate is daunting. Yerkes Observatory: It has a 40" refractor located in Williams Bay, Wisconsin, USA and is operational since 1897. KISO Observatory: It is located in Japan and uses a Schmidt telescope, operational since 1975 Uppsala University Observatory: it uses a Schmidt telescope located in Kvistaberg, Sweden and is operational since

1963. KITT Peak National Observatory has 150" mirror, located in Arizona, USA operational since 1973. Paris Observatory: It has a 33" refractor, located in Meudon, France, operational since 1889. UBC & Laval University observatory is located in Vancouver, Canada. It has a telescope with 106" reflector and has been operational since 1992. Canada France Hawii (CFH) telescope is also located in Mauna Kea, jointly run by three countries. Postdam Observatory in Germany has a 31" refractor, operational since 1899. Nice Observatory in France has 29" refractor, operational since 1886.

Modern observatories are almost like cities with laboratories, engineers, electronic workshops, living quarters, offices and shopping centers. However, telescopes can be operated by remote control. Most observatories are located in the southern hemisphere because skies are clearer.

AASTO - Automated Astrophysical Site Testing Observatory - is located on the South Pole. Extreme cold and dry conditions make it the finest site for observing stars and galaxies. A variety of telescopes are being constructed here. Scientist from 5 countries USA, UK, Sweden, Germany and Australia are taking part in the work.

Chandra X-ray Observatory: it was launched and deployed by Space Shuttle Columbia in July of 1999, is the most sophisticated X-ray observatory built to date. It is named after the Nobel Prize-winning Lahore born Indian-American astrophysicist S. C. Chandra (1910-1995). It is designed to observe X-rays from high energy regions of the universe, such as the remnants of exploded stars.

The Observatory has three major parts: (1) the X-ray telescope, whose mirrors focus X-rays from celestial objects. (2) The science instruments, which record the X-rays so that X-ray images, can be produced and analyzed. (3) The spacecraft provides the environment necessary for the telescope and the instruments to work.

Chandra's unusual orbit was achieved after deployment by a built-in propulsion system which boosted the observatory to a high earth orbit. This

orbit, which has the shape of an ellipse, takes the spacecraft more than a third of the way to the moon before returning to its closest approach to the earth of 10,000 kilometers (6200 miles). The time to complete an orbit is 64 hours and 18. On August 12, 2000 it completed an outstanding first full year of observations. About 450 sources were observed, ranging from Comet LINEAR (1999 S4) in our solar system, to cosmic objects ten billion light years away.

James Webb Space Telescope was launched into space in December 2021 from French Guiana. It has succeeded Hubble Telescope. It is intended to conduct infrared astronomy, its sensitivity allows to see object in spaces that are old, distant or faint. The construction cost was \$10billion. It has taken incredible pictures of distant galaxies.

J. A contemporary Muslim astronomer

Professor Saleh Mohammed Alladin (1931-2011) was an eminent astronomer from Hyderabad, India. He was director of the Nizamiyya Observatory in 1983. He retired from teaching in 1991 after heading the department of astronomy at the Osmania University for 27 years.

His principal area of research was dynamics of galaxies. He authored dozens of scholarly articles and a book on astronomy. In 1981 he was awarded Meghnad Saha Award for Theoretical Sciences, accompanied by a National Fellowship for two years. He had delivered lectures in the UK, Italy and the USA, besides various universities of India. He was educational advisor of former President of India, APJ Abdul Kalam.

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