The Development of Astronomy: Role of Ancient Arabian and Egyptian Scientists

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Abstracts

The modern Astronomy is based on the findings and thinking of the people of historical age. If no one knows the base and work of the previous on a subject, he or she could mere develop a new thought or findings. For, a civilization must know its past. Hence, the present work is a small effort to find out the contribution of ancient Arabian and Egyptian scientists in the field of Astronomy. Different scientists of different school of thought, correlating different streams of science being Astronomy as a main subject, are described in the present work.

Key Words: ancient arabs, egyptian scientists, astronomy, role

Astronomy (*'Ilm al-Hay'ah*) or the science of formation (i.e. of the heavens) deals with such things as the structure of the heavens, the number and configuration of the stars, the signs of the zodiac, the distances of the stars, their size and their motions. It also deals with the compilation of planetary tables, the catalogue of stars for the making of calendars and similar tasks.

The Arabs took a keen interest in the study of heavens. They developed this interest firstly, because they had once worshipped heavenly bodies, **(1)** and secondly, because the dwellers of the desert who usually traveled at night in connection with trade, war and migration from one place to another, found the direction of their journey with the help of the stars. The clear sky of the desert gave them a chance of making precise observations. Thus there was some locally acquired knowledge of the fixed stars, the movements of the planets and the changes of the weather.

After the advent of Islam, the Muslims had to determine the time of the prayers and the direction of the *Ka'bah* to turn their faces towards it at the time of prayers. For this purpose it was necessary to know the altitude of the sun and the latitudes and longitudes of all the places where the Muslims lived. The same need arose for the orientation of the mosque. This gave a religious impetus to the study of astronomy and the allied subjects such as astronomical geography and mathematics. On the other hand, the Muslims,

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who once carried on flourishing trade all over the world and occasionally launched *Jihad*, had to travel on the land and the sea. As an aid to travel, navigation and meteorology, a by product of navigation, they needed star maps. The necessity of such maps was also a cause of their interest in astronomy.

There was a group of astronomers who believed in the influence of heavenly bodies on the terrestrial affairs, and the fate and future of human beings. According to them, the prognostication of sub-lunar events from the revolution of the heavens, the signs of the zodiac in the ascendant and the motion of the planets was possible. The science dealing with such influences was termed as *Astrology (’Ilm-Ahkam al-Nujum).* Astrology, as a part of astronomy, was studied and developed by ancient Babylonians. The study of this art or science was then made in Greece and Rome, a few centuries before the opening of the Christian era. It was also cultivated in India, China and Egypt. From the 7th to the 13th century it was further developed by the Muslims and later on by the Europeans. In the 14th and the 15th centuries, the astrologers had great influence on the kings of the European countries. **(2)** The orthodox Muslims did not believe in the influence of the heavenly bodies on fate or the future of human beings.

The regular study of astronomy and mathematics was begun at Baghdad in the second half of the 8th century during the reign of the second ‘Abbasi Caliph *Al-Mansür*. After that the patronage and generosity of other Muslim rulers, particularly of the seventh ‘Abbasi Caliph *Al-Ma’mun*, provided stimulation to the astronomical and mathematical researches of every kind. Indian, Persian and Greek astronomical works were translated into Arabic, and for making the astronomical observations the observatories were established by the caliphs and private persons at various places in the Muslim world. Astronomy was studied with great interest with the result that the number of Muslim astronomers raised surprisingly in a short period of time, and by the end of the 10th century, a large number of eminent Muslim astronomers gathered in Baghdad. In the 11th and the 12th centuries astronomy flourished in Muslim Spain where a good deal of creative and original work on this branch of science was done.

The Muslim scientists attached utmost importance to accuracy in observations and calculations, without caring for the length of time needed for it. Thus sometimes their astronomical researches extended for more than forty years. Due to this desire of accuracy the Muslims did not accept as such the astronomical tables or measurements of Ptolemy, a great Greek astronomer and mathematician. They only accepted his planetary theory just to provide a basis for astronomical research. They themselves conducted astronomical researches in Baghdad, Samarqand, Nishapur, Cordova, Damascus and Ray, and after making a careful study of the heavens they not only corrected and amplified Ptolemy’s astronomical tables, but also compiled a number of new ones and drew up new star catalogues. On the basis of fresh observations, the Ptolemaic system was repeatedly criticized by the Muslim astronomers, particularly those of Spain.

The investigations on astronomy were continued, and till the end of the 11th century, nearly all the original and creative work was done by Muslims, and even the works of non-Muslims were written in Arabic. Astronomy reached its highest in the 13th and 14th centuries. In the 12th century, the Christians and Jews started the work of translation from Arabic into Latin and Hebrew, and began to conduct research in this field. But until the end of the 13th century, no mathematical and astronomical work comparable to that of the Muslims could be produced by the Christians or Jews. It is interesting to note that in the 12th century, while Ptolemy's astronomical work, *Almagest,* after a thorough study and research, was subjected to severe criticism by Muslims particularly those of Spain, the study of this work was begun in the Latin world.

Besides compiling the astronomical tables, the Muslims prepared celestial globes on which the positions and magnitudes of the stars were represented. The globe is of Greek origin, but since Ptolemy's time there has been a continuous improvement on it. The Muslim scientists also wrote comprehensive books on astronomy and mathematics, and also composed treatises on various branches of this science.

The Muslim astronomers also prepared the star maps to preserve the old astronomical knowledge, and to use them as an aid to travel, navigation and meteorology.

A great incentive for the study of astronomy came from an Indian astronomical work called *Siddhanta* which was brought to the court of Baghdad by a Hindu named *Kanka*. *Kanka* met *Ya'qüb Ibn Tãriq* in 767 who was one of the greatest astronomers of his time. *Ya'qüb Ibn Tãriq* introduced him to the Caliph *Al-Mansür***.(3)** *Kanka* showed the book to the Caliph who ordered *Muhammad Ibn Ibrahim Al-Fazãri* to translate it into Arabic.**(4)** He also ordered that a work based on *Siddhanta* should be composed, which could serve as a reference book for the Arabs. *Muhammad Ibn Ibrahim* took this responsibility and prepared a book which was called by the astronomers as *Sind Hind al-Kabir* (the great *Siddhanta).* **(5)** It was used until the time of the Caliph *Al-Ma'mun*. Then *Al-Khwãrizmi*, who was one of the greatest scientists, prepared a summary of this book. He also compiled astronomical and trigonometrical tables according to the combined methods of Indians, Persians and Greeks. These tables were revised by *Maslamah al-Majriti* (c. the second half of the 10th century). They gained so much popularity that they were used even in China. In the 12th century, the translation of these tables was made into Latin. **(6)** *Al-Khawarizmi* glimpsed in his works on astral motion and the force of attraction the law of universal gravitation.

The astronomer *Ibrahim Ibn Habib al-Fazãri* was the first Muslim who constructed astrolabes. He composed a poem on astrology, and compiled a *Zij* (calendar) according to the Arab method. He also wrote on the use of astrolabes and on the armillary spheres. **(7)**

In 762-63 the Persian astronomer and engineer, *Naubakht*, together with *Masha' Allah* (Latin Macellama, Macelarama, Messahala), made a survey before the building of Baghdad. Masha' Allah (d. 815 or 820) was one of the earliest astronomers and astrologers, who flourished under the Caliph *Al-Mansür*. **(8)** *Naubakht* (d. 776-77) was the author of a book on astrological judgments entitled *Kitäb al-Ahkam.* **(9)**

During the reign of the Caliph *al-Ma'mun*, the important work of translation of Ptolemy's *Almagest* from Greek into Arabic was completed. The Caliph was very anxious to get it translated correctly. It was translated several timed. Many commentaries on it were written. Its summaries were also made. The Minister *Yahya Ibn Khalid Barmaki* was the first to get it translated. A group of scholars wrote for him a commentary on this book, but he did not like it. He appointed *Abu Hasan* and *Salman* who were attached to the scientific academy called *Bait al-Hikmah* (The house of wisdom) to write a commentary on it.**(10)** The *Almagest* represents the best example of Greek classical works on astronomy. It served as a basis for the later astronomical works. *Al-Hajjaj Ibn-Yusuf* was one of the first translators of the *Almagest.* He made this translation on the basis of a Syriac version. **(11)**

The Caliph *al-Ma'mun* (169-218 / 786-833) was very fond of philosophy and science. The more he got acquainted with the interesting problems of science, the more his interest grew in the practical work. He built an observatory at Baghdad in his *Bait al-Hikmah* and another in the plain of Tadmor (Palmyra). In these observatories the fundamental elements of the *Almagest* like the inclination of the ecliptic, the length of the solar year, and the precession of the equinoxes were verified. Observations on the celestial motions were carried out and geodetic measurements were made. **(12)**

Al-Ma'mun ordered *Ahmed*, *Muhammad* and *Hasan*, who were eminent scientists and his courtiers, to measure in collaboration with other court scientists the length of the terrestrial degree and the circumference' of the earth in some vast planes. The planes of Sinjar and Tadmor were selected for this purpose. The astronomers stayed at a place and noted with the help of instruments the altitude of the North. Pole, and pitched a nail there. Then tying a long rope with the nail, they carried the rope in the direction of the North. Where the rope ended they pitched another nail and tied another rope with it, and proceeded in the same direction. They continued this process as well as observations on the altitude of the North Pole, until on reaching a particular spot they noticed that the altitude of this Pole had increased by one degree. The distance they covered was also measured, which was found to be 56 2/3 miles. From, these observations it was inferred that for each terrestrial degree the distance covered on the earth amounts to 56 2/3 miles. The same operation was repeated in the direction of the South where at one spot they noticed that the altitude had decreased by, one degree. The distance covered was the same as in the first case. Now on multiplying this distance by 360 which is the total number of terrestrial degrees, the circumference of the earth was found to be equal to 20,400 miles, and the diameter equal to 6,500 miles. **(13)**

The chief of astronomers who carried observations under *al-Ma'mun* was *Sanad Ibn 'Ali*. He was a Jewish convert to Islam. He constructed an observatory (Kanisah) at the back of the Shamãsiah Gate at the palace of *Mu'izz al-Dawlah* in Baghdad. An astronomical table and some writings on astronomy and mathematics, including a book on Arabic numerals, are ascribed to him. **(14)**

'Ali Ibn 'Isa al-Astur1ãbi who flourished in Baghdad and Damascus in the first half of the 9th century, took part in the measurement of the length of the terrestrial degree ordered by *al-Ma'mun*. He made astronomical observations at Baghdad and Damascus from 829 to 833. He was the famous constructor of astrolabes; hence the nickname *al-Asturlãbi* (maker of astrolabe). He wrote a treatise on astrolabes, which is one of the earliest works on this instrument. **(15)**

Yahya Ibn Abi Mansür also took part in the observations made at Baghdad in 829-30, and compiled the astronomical tables called *Ma'munic* tables. Like the tables of Habash these, too, are a collective work of 'various astronomers. *Al-Marwarudhi*, who also flourished under *al-Ma'mun*, made solar observations. **(16)**

In the 9th century astronomy flourished in the East, Astronomical researches were conducted in the observatories of Baghdad, Damascus and other places. More original and improved work was done in the second half of the 10th century. The elaboration of trigonometry, which was considered to be a branch of astronomy at that time, was also continued. A great attention was paid to the construction of good astronomical instruments, especially to the spherical astrolabe which was newly introduced at that time. *Hamid Ibn 'Ali* was a famous constructor of spherical astrolabes. *Jãbir Ibn Sinan* was also a maker of this as well as of other astronomical instruments. According to *al-Biruni,* he was the first to make a spherical astrolabe. *Al-Nairizi* wrote on this instrument an elaborate treatise which represents the best Arabic work on this topic. In this treatise the author, after giving the introduction, describes the instruments, and gives its applications. Beside this work, *al-Nairizi* compiled astronomical tables. A great scientist *al-Mähani* made for 33 years (833—886), a series of observations on lunar and solar eclipses and planetary conjunctions. Another astronomer of this time *Ahmad al- Nahâwandi*, who flourished at the time of *Yahya Ibn Khalid Ibn Barmak*, made astronomical observations at Jundishapur and compiled tables called *Mushtamil.* **(17)**

After carrying out astronomical observations for ten years (825 to 835) *Habash al-Hãsib* compiled three astronomical tables. The first were according to the Hindu method (based on *Siddhanta).* The second called *Al-Zij al-Mumtahan* (the "tested Tables") were according to the Arab method. They were very important and were probably due to the co-operative efforts of *al-Ma'mun*'s astronomers. The third called *Al-Zij Al-Saghir* (the small tables) was commonly known as the *Tables of Shah. Habash al-Hãsib* determined the time of the solar eclipse of the year 829. He was the first to determine time by an altitude (in this case, of the sun). This method was generally accepted and adopted by Muslim astronomers. **(18)**

The most illustrious scholar of this age, and one of the greatest astronomers of Islam, was ‘*Abd Allah Muhammad Ibn Jãbir Ibn Sinan al-Battãni* (Latin; Albategnius, Albatenius). His ancestors were Sabeans of Harran, but he himself was a Muslim. He carried out astronomical observations of a wide range and with remarkable accuracy for about 41 years (877—918). He determined many astronomical co-efficients, like the precession 54.5” a year, inclination of the ecliptic 23° 35’, with great accuracy. He noticed an increase of 16° 47’ in the longitude of the sun’s apogee since Ptolemy’s time. This led to the discovery of the motion of the solar apsides and of slow variation in the equation of time. *Al-Battãni* proved the possibility of the annular eclipses of the sun. He also wrote many astrological works. His main work is a large astronomical treatise including the astronomical tables. His tables contain a catalogue of fixed stars for the year 880—81. His work is an advance on that of *al-Khwãrizmi*, and shows more divergence from Indian methods. Observations regarding the first appearance of the new moon, the length of the tropic and sidereal year, the obliquity of the ecliptic, the lunar anomalies, the parallaxes, etc., are more complicated and more accurately made by *al-Battãni* than by *al-Khwãrizmi*

Al-Battãni’s astronomical treatise was translated into Latin and Spanish in the 12th and 13th centuries respectively. It exerted a great influence on the European scholars of the middle Ages and Renaissance. **(l9)**

Thãbit Ibn Qurrah (d. 901) who was a physician, mathematician, astronomer and translator from Greek and Syriac into Arabic published his solar observations made at Baghdad. He particularly determined the altitude of the sun and the length of the solar year. **(20)**

The astronomer and mathematician *Wijan Ibn Rustam al-Kühi* wrote many astronomical and mathematical works, including a treatise on the construction of the astrolabe. He was the head of the astronomers working in 988 at the *Buwayhid Sharaf al-Dawlah*’s observatory. **(21)** His co-worker *Ahmad Ibn Muhammad al-Saghâni* was the inventor and maker of astronomical instruments. *Abu’l-Wafã* is said to be the discoverer of the variation, the third inequality of the moon; a discovery which was later ascribed to Tycho Brahe. **(22)**

‘*Ali Ibn al-Husain al-’Alawi* (d. 985) showed a remarkable accuracy in observations. He compiled astronomical tables which remained very popular for at least two centuries. **(23)**

Now we come to a famous astronomer of the 10th century, named *Abu'l-Husain 'Abd al-Rahman al-Sufi*. He was born in Ray (Persia) in 903, and died in 966. He was a prominent astronomer of the medieval times. His knowledge of both the Islamic and Greek astronomy, particularly uranometry, was comprehensive. He was the first to observe the change of the colour of stars, the change in the magnitude of stars, the proper motion of stars, the long period variable stars and the Southern constellations which have been wrongly ascribed by modern astronomers to some later ones.

Abd al-Rahman al-Sufi was patronized by the Buwayhid ruler Adud al-Dawlah (949—982) who was a great patron of astronomy, and had built an observatory at Shiraz. *Al-Sufi* wrote for the ruler a book on uranometry, entitled *Suwar al-Kawàkib* (The book of the fixed stars). In this book he gives a complete description of the constellations of the heavens. He also gives the position of each star of the constellations, illustrating with pictures. The book contains 55 astronomical tables along with illustrations of 48 constellations in 96 diagrams as seen in the heavens. The artistic value of the pictorial illustrations in the Mss. of this work is very great, and represents one of the best examples of the Persian miniature paintings. *Al-Sufi* has not only corrected the errors of observations in the work of his predecessors like *al-Battãni*, but also, pointed out many faulty observations found in Ptolemy's *Almagest.* He defined carefully the boundaries of each constellation, and recorded the magnitudes and positions of stars after making new observations.

The *Suwar al-Kawàkib* is one of the three masterpieces of observational astronomy of the medieval times; the other two being the catalogues of *Ibn Yünus* and *Ulugh Beg* prepared in the 12th and 15th centuries respectively. It is an addition to the Muslims' knowledge on uranometry. The later astronomers, like *al-Biruni*, *Alfonso*, Prince of Castile, *Khwãjah Näsir al-Din Tusi*, Prince *Ulugh Beg* and *Jai Singh II,* based their catalogues of stars on this authentic catalogue. This work was translated into Latin, French and Persian, and a commentary on it was written in Spanish.

It served as a basis for later works in Western Europe. The modern astronomers like Hauber, Down, Argelander, Ideler, Schellerup and Knobel had made an extensive use of it.

Al-Sufi prepared a fine celestial globe. Several celestial globes which cover the period from the 11th to the 18th century show the star positions and magnitudes according to *al-Sufi*. He showed a remarkable accuracy in the design of the astrolabes. He wrote a treatise on this instrument. In this treatise he throws light on the astronomical techniques as practiced it that time. **(24)**

Another great astronomer and one of the greatest Muslim astronomers was *Abu'l-Hasan Ali Ibn Abi Said 'Abd al-Rahman Ibn Ahmad Ibn Yünus al-Sadafi*, generally known as *Ibn Yünus*. He was well versed in Arabic literature, poetry and history, and had knowledge of many other subjects. He belonged to Egypt where he died in 1009. He was a courtier of the Fatimi Caliph *al-'Aziz Billah* (975—996). He got a chance of working in a well-equipped observatory which was the part of a Muslim academy of science, named *Dar al-Hikmah* (the house of wisdom) founded in Cairo by the Fatimi rulers. He made astronomical observations, and by the order of the Caliph *al-'Aziz* he compiled the astronomical tables. The work of compilation of these tables was begun in 990 during the lifetime of the Caliph, but it was completed after his death under his son *al- Hakim* (966—1020). Hence they were named after him *Al-Zij al-Kabir al-Hakimi.* In these tables he entered his observations about the eclipses and conjunctions, old and new, improved values of astronomical constants (inclination of the ecliptic, 23° 35'; longitude of the sun's apogee, 86° 10'; solar parallax reduced from 3' to 2'; precession, 51.2" a year). He gave an account of the geodetic measurements which were carried on by the order of the Caliph *al-Ma'mun* in the ninth century.

Ibn Yünus in his astronomical tables (written in 4 volumes) corrected the errors of observations in the astronomical tables of his predecessors. The people of Egypt relied on these tables. It is said that after their compilation the use of all the previous tables in the world was given up. Even the astronomers of China greatly utilized them. The translation of a large part of the tables, except the chronological section, has been made in French in 1804.

Beside these-tables, *Ibn Yünus* has composed many books. One of these is *Jadawil al-Samt* (the tables of direction), and the other is the *Jadawil al-Shams wa'l-Qamar* (the tables of the sun and the moon). **(25)**

A famous astronomer of the 11th century, who belonged to Cordova (Spain), was *Abu Ishaq Ibrahim Ibn Yahya al-Naqqàsh*, commonly known as *Ibn al-Zarqàli* or *al-Zarqàli* (Latin: Arzachel). He was also an eminent astronomer of this century. He lived from 1029 to 1087. He was the best observer of his time, who made astronomical observations for about 19 years (1061—1080). He invented an improved astrolabe called S*afihah (Saphaea Arzachelis)* on which he also wrote a treatise. It was translated into Latin, Hebrew and many vernaculars. *Al-Zarqàli* was the first to prove explicitly the motion of the solar apogee with reference to the stars. According to his calculations it was equal to 12.04" per year (the real value being 11.8"). He edited the planetary tables called *Toledan Tables.* These tables were probably the result of the observations made in Toledo by him and by a great observer *Ibn Said* in collaboration with other Muslim and Jewish astronomers. They were translated into Latin and enjoyed much fame. **(26)**

A famous astronomer, mathematician and poet, *'Umar Ibn al-Khayyãm,* reformed the old Persian calendar which had been replaced by the Islamic calendar after the Muslim conquest of Persia. This reformed calendar was called *Al-Tàrikh al-Jalãli* after the name of the Saljuq Sultan *Malik Shah Jalal al-Din* who in 1074-75 called '*Umar*

Ibn al-Khayyãm to his observatory for making this reform. Many interpretations have been given to it. Each interpretation is accurate to a certain degree, but at any rate '*Umar*'s calendar was probably more accurate than the Gregorian (Christian) calendar. Three interpretations, the second of which seems to be the most accurate, are being quoted here along with the authority giving the interpretation and the resulting error.

1. *Al-Shirãzi*'s interpretation: 17 intercalary days in 70 years;' error. 1 day in about 1540 years.
2. *Ulugh Beg*'s interpretation: 15 intercalary days in 62 years; error, 1 day in about 3770 years.
3. Modern interpretation: 8 intercalary days in 33 years: error, 1 day in about 5,000 (in the Gregorian calendar there is an error of 1 day in 3330 years). **(27)**

The greatest astronomer of the 12th century, who also belonged to Spain, was *Abu Muhammad Jãbir Ibn Aflah*. He was born or lived in Seville. He vigorously criticized the Ptolemaic theory of planets, and wrote a book on astronomy entitled *Islah al-Majisti* (the correction of the *Almagest).* He was of the view that the lower planets Mercury and Venus), at least, must have visible parallaxes. Venus may happen to be exactly on the line joining the sun and the earth. The most important part of his book is the introduction on trigonometry. The book was soon translated into Latin and Hebrew. *Jãbir Ibn Aflah* is said to be the inventor of the astronomical instrument called turquet *(torquetum)* which contains two graduated circles in two perpendicular planes. The same invention has also been ascribed to two other persons, namely, Frances of Leige (11th century) and *Näsir al-Din Tusi* (13th century). The turquet was introduced into the Latin West by Regionomentus. It gained a great popularity in the 15th and 17th centuries. **(28)**

Another astronomer of the time was *Abu'l Qãsim Hibat Allah Ibn Husain al-Badi' al-Asturlãbi*. He was also a physician, mathematician, poet and litterateur. He was the greatest expert of his time in the knowledge and construction of astrolabes; hence his nickname *al-Asturlãbi*. In 1120—30 astronomical observations were made under his direction, and astronomical tables were compiled. The observations were carried out in the palace of the Saljuq Sultan of Iran, *Mughith al-Din Mahmud* (1117—1131). The tables were dedicated to the Sultan, and were called after him the Mahmudic tables. *Al-Asturlãbi* was very much praised by Muslim biographers. He died in Baghdad in 1139-40. **(29)**

In the 13th century there flourished in the East a great scholar of Persian origin, named *Abu Ja'far Muhammad Ibn Muhammad Ibn al-Hasan, Näsir al-Din al-Tusi al-Muhaqqiq,* (the researcher). He was born in Tus (Khurasan) in 1201, and died in Baghdad in 1274. He was a philosopher, mathematician, astronomer and physician. He was one of the greatest Muslim mathematicians and scientists. He wrote both in Arabic and Persian. It is said that he knew Greek as well. He joined the Mongol service, and was later made administrator of the *Waqf* revenues.

While he was administrator he resided at Maragha in Asia Minor (1259—1274). Here he made astronomical observations in an observatory established by the Mongol ruler *Hulagu Khan II* after he had defeated the last ‘Abbasi Caliph, *al-Mu’tasim*, in 1258. A library was attached to it. It is said to have contained 4, 00,000 volumes which the Mongol armies had collected in Syria, Mesopotamia and Persia. *Näsir al-Din* was the first director of this observatory. He was succeeded by two of his sons.

Näsir al-Din was well acquainted with the knowledge of the Greeks. He wrote about 64 works on many subjects. Here we shall, consider only some of his astronomical and astrological works. The most important astronomical work of *Näsir al-Din* is the *Tadhkirah fi ‘Ilm al-Hay’ah* (The description of astronomy) which is a condensed summary of astronomy. To explain it many commentaries and super commentaries have been written. The work enjoyed much popularity, it consists of four chapters. The second chapter, beside other things, contains interesting criticism of the Ptolemy’s *Almagest* in which he showed a great ingenuity. The criticism chiefly concerns the anomalies of the moon, and the motion in the latitude of the planets (particularly Mercury and Venus) ; also the proposition of a new system to replace the complicated Ptolemaic machinery of deferents and epicycles. His new and forceful criticism of astronomy as well as of other Muslim astronomers helped Copernicus in making his reform’. *Näsir al-Din* wrote one treatise on the five quadrants and two treatises on astrolabe. He also wrote two treatises on calendar.

Näsir al-Din made observations in the observatory at Maragha which was well equipped with good astronomical instruments. He prepared new astronomical tables called after the Mongol ruler, *Al-Zij al-Ilkhäni. Nasir al-Din* asked the ruler to give him a period of 30 years to compile the tables, because it was the shortest period during which the planetary cycles were completed. But the ruler refused, and gave him only 12 years to accomplish this task. *Nasir al-Din* tried a succeeded in completing the tables within this time. They were based upon new observations. But the use of the earlier ones had also been made.

The Zij-*i- Ilkhäni was* originally written in Persian. It consists of four books dealing respectively with (a) Chinese, Greek, Arabic and Persian Chronology; (b) motions of the planets; (c) ephemeredes and (d) astrological operations. The translation of the *Zij* was made into Arabic, and commentaries on it were written. Finally, a sort of supplement to it was compiled by *Jamshed Ibn Mas’üd al-Käshi* (d. 840/1436), the first director of Ulugh Beg’s observatory in Samarqand. These tables enjoyed a great popularity in the East including China, and were, continued to be used even after the compilation of new tables by Ulugh Beg in 1437. **(30)**

A contemporary of *Nasir al-Din*, *Mu’ayyid al-Din al-Urdi al-Dimashqi* also took part with him in compiling the tables. He was a Syrian astronomer, architect and engineer. He started his career as a technician in Syria. He did some hydraulic work in Damascus, and also constructed there an astronomical instrument for *al-Mansür*

Ibrahim (King of Hims, 1239—1245). In about 1259 he went to Maragha, and helped *Nasir al-Din* in organizing the observatory and compiling the tables. It seems that the instruments, remarkably precise, were constructed under his supervision in the foundry attached to the observatory.

Al-Urdi was the author of a treatise in which he also described the instruments used in the observatory of Maragha, and explained their use and construction. The instruments are as follows:—
(1) mural quadrant (2) armillary sphere (3) solstitial armil (4) equinoctial armil (5) Hipparch's diopter (alidade); (6) instrument with two quadrants (7) instrument with two limbs (8) instruments to determine sines and azimuths (9) instruments to determine sines and versed sines, (10) the perfect instrument (a universal instrument) (11) parallactic ruler (after Ptolemy).

Al-Urdi was also the author of two other treatises; one on the construction of a perfect sphere and another on the determination of the distance between the centre of the sun and the apogee. He compiled astronomical tables, and wrote on Ptolemaic astronomy.

In 1279 or 1289 *al-Urdi*'s son *Muhammad* made a celestial globe. It consisted of two brass hemispheres separated by the ecliptic. Its diameter was 140 mm. It had a horizon circle. Two movable half circles were attached to the zenith point by a pivot. These circles are graduated and are used to determine the declination and right ascension of any star. Forty-eight constellations, the equator and the ecliptic are inlaid with silver or gold. It is preserved in the mathematical salon of Dresden. **(31)**

The works of Muslim astronomers were later translated into Latin, Hebrew and vernaculars by the Christian and Jewish scholars, some of the technical terms including azimuth *(al-Samt),* Algol *(Alfol),* Achernar *(Akhir al-Nahr)*, passed into the European languages. The names of many stars such as akrab *(Aqrab),* Algedi *(al-Jadi,* the kid), Altair *(al-ta'ir ,*the player), Denab *(dhanb,* tail), Pherkad *(Farqad*, calf), Adara (*'Adhrah)* Aldebaran *(al-dibràn),* which are of Arabic origin, also passed into these languages. The stars being countless in number, their separate study is not possible. They were, therefore, divided into various groups, and the groups were named after the things and animals with which they resembled.

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