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Samarkand

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SAMARKAND

It is difficult to place a date on the founding of Samarkand,Ancient Marakanda, city of Transoxiana, now capital of Uzbekistan, although it is reputed to have been established as a frontier outpost in the mid sixth century B.C. by Cyrus the Great as protection against incursions by central Asian nomads.[1] The city was known to Europe in classical antiquity as the capital of Sogdiana and was captured by Alexander on his campaign into India, but it was usually dominated by Turko-Mongol elements.[2] It was an important stop on the East-West trade route, one of the last major outposts for the merchant traveling east before reaching the Jaxartes and entering the vast and sparsely populated inner Asian steppe.[3]

Conquered by the Arabs in the early eighth century, Samarkand became one of the easternmost outposts of Islam and, along with Bukhara, one of the foremost cities of Mawara' al-Nahr (the land beyond the river).[4] Following the collapse of the Samanids in the late tenth century, Samarkand passed from one Turko-Muslim dynasty to another, first dominated by the Ghaznavids, then, in quick succession, the Oarakhanids, the Seljuks and ultimately by Khwarizmshahs.[5]

Samarkand highlights with great perfection the great misfortunes which caused the woes of Muslim scholarship following various invasions. In the case of Samarkand the invaders were the Mongols. Early in the 1220s, the Mongols went on the move, and the whole of eastern Islam was devastated by them. In just one year the Mongols seized the most populous, the most beautiful and the best cultivated parts, whose inhabitants excelled in character and urbanism[6]and inflicted all ills on them. An army under Jenghiz Khan's son Jagtai, captured and sacked Otrar, whilst another under Jenghiz himself, burned Bukhara to the ground, raped thousands of women, and massacred 30,000 men.[7] Samarkand was one of the main victims of the Mongol onslaught and just like Balkh, it refused to war against the Mongols. It surrendered peacefully, with the hope to be spared devastation. It suffered pillage, and wholesale slaughter. Fourteenth-century travelers lamented that the city which they saw was only a shadow of what pre-Mongol Samarkand must have been, although even in ruins the city impressed them.[8] Ibn Battuta describes Samarkand just as Balkh, as still largely in ruins.[9] The population had been largely wiped out, a total of 1.3 million people were killed in the whole region.[10] Mongol devastation left little of the schools, madrassas, and trade networks. Also the victims, in great numbers, were scholars. One of the most illustrious scholars to be slain by the Mongols was Najib al-Din al- Samarkandi.

[1]R. Hattox: Samarkand: *Dictionary of the Middle Ages:* Vol 10; J.R. Strayer Editor in Chief; Charles Scribner's Sons, N. York; 1980 fwd; pp 640-1.
[2]R. Hattox: Samarkand:; pp 640-1.
[3]R. Hattox: Samarkand:; pp 640-1.
[4] R. Hattox: Samarkand; pp 640-1.
[5] R. Hattox: Samarkand; pp 640-1.
[6] B. Spuler: *History of the Mongols;* London, Routledge& Kegan Paul, 1972. p.31.
[7] W. Durant: The Age of faith, op cit; p.339.
[8] R. Hattox: Samarkand; op cit; pp 640-1.
[9]Ibn Battuta: *Travels in Asia and Africa;* trans and selected by H.A.R. Gibb; George Routledge and Sons Ltd; London, 1929.
[10]E.G. Browne: *Literary History of Persia*; Cambridge University Press; 1929; 3 Vols; Vol 2; p. 439.

Najib al-Din Al-Samarkandi

Najib al-Din Al-Samarkandi was a physician who was born or flourished at Samarkand, killed by the Mongols during the sacking of Herat in 1222-1223. [11]He wrote various medical works in Arabic, the most important was entitled *Kitab al-asbab wasl-alamat*- (causes and symptoms (of diseases). He wrote on the treatment of diseases by diet, and wrote on simple drugs (*al-Adwiya al-Mufrada*) The popularity of his *Kitab al-ashab* is highlighted by the number of copies of the manuscript.[12] It was known also through a commentary completed in Samarkand, 1423-1424, by Uluh Beg's physician, Al-Kirmani. The *Sharh (or mamzuj al-ashab wal-alamat*) is a commentary and is itself the nucleus of the Persian treatise *Tibb i-Akbari* (medicine of Akbar) completed in 1700-1701.[13] One, or the principal contributions of Al-Samarkandi, was to question the old Greek ideas. One of his most interesting medical works with regard to pharmacology is his *Aqrabadhin*[14]- Medical Formulary. The treatise is called *Kitab al-qarabadhin ala tartib al-ilal,* (treatise on the medical formulary on compounding for diseases,') whose English translation is by M. Levey and N.al-Khaledy.[15] In a lengthy introduction, Al-Samarkandi attempts to rationalise his pharmacology and therapy and is therefore a matter of great interest to the history of medicine.[16] Without voicing open objections to all the contemporary pharmacological ideas of his day, he nevertheless, frequently avoided use of the humoral pathology and gave his own reasons for the compounding of drugs and the relative quantities used under certain condition.[17] Al-Samarkandi gave his reasons for compounding drugs. The circumstances leading to the use of compound remedies involve various conditions:

> *`It is partly because of the nature of sickness and disease, partly because of the state of the organs, and partly because of the drug. For the use of compounded drugs there are fourteen reasons. One of them is due to the extent of the ill humor if there is no drug opposite to it in strength. It is then compounded from one which is stronger in the quantity of its humor with one which is less so. From these a blend is put together to resist that ill humor. The second is concerned with the strength and acuteness of the illness when there is no single drug which can resist it. It is then compounded so that the constituents may assist one another in resistance. Third, there are the differences in the state of the disease and attendant circumstances, and its treatment; a drug is unknown which (by itself) performs opposite actions like absorbing (jala) and bringing up (tamlis) in chest ailments, and the freeing (tahlil) and hindering of tumours, so that one must be compounded. Fourth is a basic one: a means to counteract many poisons and different ailments. This is the noblest of compound ones because it protects one from constriction with a strength superior to the strength of any element. Its effectiveness is due to the strength of its elements. The fifth has to do with the remoteness of the ailing organ from the stomach. It is compounded with a drug which is useful for it and (with one which) makes it reach the organ quickly as saffron and camphor, and Chinese cinnamon with haematite. The sixth concerns the*

[11]G. *Sarton: Introduction to the History of Science;* in 3 vols; The Carnegie Institution; Washington; 1927 fwd; vol II; p.661.
[12] Sarton II; p.661.
[13] Sarton II; p.661.
[14] Manuscript at Aya Sofya, Turkey, 3555, and also Leiden, Holland, 1353.
[15] M. Levey and N. Al-Khaledy: *The Medical Formulary of al-Samarqandi*; Philadelphia; 1965;
[16] M. Levey: Influence of Arabic Pharmacology on Medieval Europe; in *Convegno Internationale: Oriente e occidente Nel Medioevo Filosofia E Scienze;* 9-15 Aprile 1969; Academia Nationale Dei Lincei; Roma; 1971; pp. 431-44. p. 434.
[17] M. Levey: Influence of Arabic Pharmacology; p. 435-6.

strength and importance of the organ and its size and functions. A drug is mixed to dissolve tumours and to ease (at the same time) the properties which lessen a drug's effectiveness to act as a restraining remedy. The seventh relates to the unsavouriness of the drug and its disagreeableness until it is improved to the point of acceptability by nature. The eighth has to do with the increase of potency of a drug as in mixing ginger with turpeth. The ninth protects some organs against the harmfulness of a drug as by correctives with purgatives, and the tenth is the inadequacy of a drug like gum Arabic in the collyrium of verdigris. The eleventh concerns the destruction of the evil property of a drug as mixing castareum with opium. The twelfth is for keeping the strength of the compounded drug for a long time as in mixing opium with the major electuaries. The thirteenth is concerned with the differences of drugs in their amounts and usages in the desired direction as in mixing a qiruti (A gloss reads: a kind of wax and oil mixture,' it generally means `cerate' or `salve used medicinally) unguent with essentials in poultices. The fourteenth is the need of a single useful remedy for an illness as in mixing the unguent with verdigris to form an effective drug for wounds when there are no other drugs good for wounds around.'[18]

It is obvious in these fourteen points, al-Samarkandi has given great emphasis to an empirical form of therapy. This development of empiricism in medicine was carried forth after the Arab period in Europe slowly but surely. The basis has been laid by al-Samarqandi and others like him for greater divergence with Galenic ideas.[19] It is the amounts of drugs used by al-Samarkandi in making up the remedies, the humoural idea is still present but well circumscribed by other determining factors considered more important by the text:

`As to the reasons for the differences in weight, there are seven simple ones as well as combinatory reasons of these simple ones. As to the seven simple ones, the first is the strength and weakness in the drug's natures. Second is the value or lack of its usefulness. Third is the importance or non existence of its benefits. Fourth is its partnership in usefulness or its being alone. The fifth is concerned with the location of the ailing organ in regard to its proximity to or distance from the stomach. Sixth is the existence or non existence of drugs in the compounded one which weakens its strength. Seventh is the existence of harmfulness in it for some organs, or for inadequacy of the drugs or their over sufficiency.'[20]

It is appropriate to note that almost all these reasons are still of importance in present day allopathic medicine.[21]

However the devastation of Samarkand did not cause it to be entirely wiped out of the land as other cities, which once boasted the glories of Islamic learning such as Merv or Nishapur, suffered. Samarkand was eventually incorporated into that part of the Mongol realm ruled by the descendants of Chagatay Khan (d. 1242).[22] From this period till much after Timur the Lame's rule, there are no scientific achievements of major importance to mention. The only scientist of some worth to have come to the fore then was Shams

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[18] Al-Samarqandi: *Aqrabadhin*; Ms. Aya Sofya; 3555; fols 4b-5a.
[19] M. Levey: Influence of Arabic Pharmacology; op cit; p. 435-6.
[20] Al-Samarqandi: Aqrabadhin; Ms. Aya Sofya; 3555; fols 5a-5b.
[21] M. Levey: Influence of Arabic Pharmacology; op cit; pp. 436-7.
[22] R. Hattox: Samarkand; op cit; pp 640-1.

al-Din ibn Ashraf Al-Samarkandi (born: about 1250 in Samarkand, died: about 1310). He wrote works on theology, logic, philosophy, mathematics and astronomy which have proved important in their own right and also in giving information about the works of other scientists of his period.[23]Al-Samarkandi wrote a work *Risala fi adab al-bahth* which discussed the method of intellectual investigation of reasoning using dialogue. He also wrote synopsis of astronomy and produced a star catalogue for the year 1276-77.[24]

By the mid fourteenth century Chagatay control of Transoxiana had been replaced by local anarchy, out of which Tamerlane (Timur-i Leng [1336- 1405]), a local chieftain with hazy Chagatay connections, emerged victorious and established Samarkand as his capital.[25] Timur's Mongol origins marked his rule by devastation of the Muslim world similar in magnitude to that the Mongols had inflicted centuries earlier. Gibbon narrates the misdeeds of Timur in Syria:

> *`the streets of Aleppo streamed with blood, and re-echoed with the cries of mothers and children, with the shrieks of violated virgins. The rich plunder that was abandoned to his soldiers might stimulate their avarice; but their cruelty was enforced by the peremptory command of producing an adequate number of heads, which, according to his custom, were curiously piled in columns and pyramids: the Moguls celebrated the feast of victory, while the surviving Moslems passed the night in tears and in chains. I shall not dwell on the march of the destroyer from Aleppo to Damascus, where he was rudely encountered, and almost overthrown, by the armies of Egypt… after a period of seven centuries, Damascus was reduced to ashes… on his return to the Euphrates he delivered Aleppo to the flames… but I shall briefly mention that he erected on the ruins of Baghdad a pyramid of ninety thousand heads.*[26]

In his wholesale orgy of slaughter and destruction, Timur spared only one group: he carried off craftsmen, including glassmakers, to Samarkand.[27] The deportation of the glassmakers from Damascus in 1400 is believed to have put an end to the manufacture of gilded and enameled vessels in western Asia.[28]

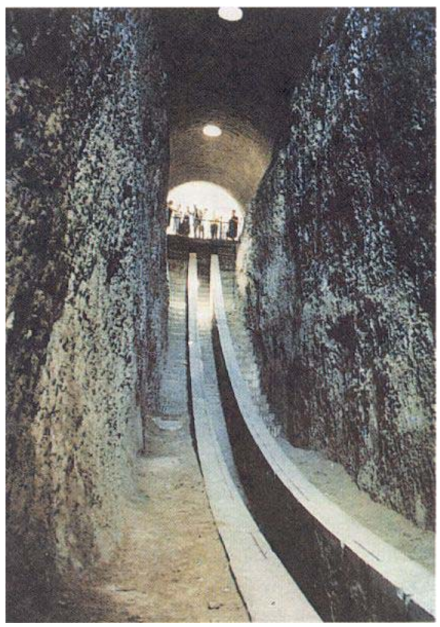
After Timur, Samarkand witnessed the best period of its scientific legacy symbolized by the construction of its famed observatory by Uluh Beg.

The Samarkand Observatory

The Samarkand observatory dates from 1424. It was built By Uluh Beg. Uluh Beg was born Muhammad Targay, the grandson of Shah Timur in 1394, and died in 1449. From 1409 he was the ruler of Maverannakher in Central Asia, the chief city of which was Samarkand (which under the reign of the Timurid sovereigns was the most flourishing centre in the whole of the Near East.) Himself a great scientist,

[23] J J O'Connor and E F Robertson: Arabic mathematics: A forgotten brilliance; at http://www-history.mcs.st-andrews.ac.uk/history/index.html
[24] J J O'Connor and E F Robertson: Arabic mathematics: A forgotten brilliance;
[25] R. Hattox: Samarkand; op cit; pp 640-1.
[26] E.Gibbon: *The Decline and Fall of the Roman Empire*; Chapter LXV; Part II.
[27] D. Whitehouse: Glass; in *Dictionary of the Middle Ages*; op cit; vol 5; pp. 545-8. p. 547.
[28] D. Whitehouse; p. 547.

he began to build the city into a great cultural centre.[29] Uluh Beg was keen to surround himself with scholars and to debate scientific questions with them.[30] It is in Samarkand, where, in 1420, he founded a madrassa in which astronomy was the chief subject. It was one of the most beautiful buildings in the whole of central Asia according to a nineteenth century historian.[31] He personally interviewed and selected whoever taught there, to determine their knowledge and qualifications. Uluh Beg led scientific meetings where problems in astronomy were freely discussed.[32] He was himself a scientist in his own merit. Uluh Beg's treatise, his Zij written in Tajik, included astronomical tables based on observations carried out at Samarkand. The third part of the introduction to this work deals with diverse problems related to planetary motion. [33] Uluh Beg analysed problems related to the determination of standard longitudes of the planets for a given period as well as their precise position.[34] He gave particular attention to practical problems concerning calculations related to the use of the tables, most of all the question of interpolation and the application of approximations resulting from the conversion of real anomalies into standard anomalies. He distinguished himself, most particularly, as a very meticulous observer.[35]



The sextant of the Ulugh Beg Observatory.

Amongst Uluh Beg's greatest accomplishments was to found in 1424 one of, if not the greatest, observatory in Islam. It was not the only one, though. Large observatories continued to be built in the Islamic world

[29] J. J O'Connor and E. F Robertson: Arabic Mathematics, a forgotten brilliance; op cit.

[30] Francoise Micheau: The Scientific Institutions in the Medieval Near East, in *Encyclopaedia of the History of Arabic Science*, 3 Vols. Edited by R Rashed; Routledge, London and New York: 1996; pp. 985-1007. at pp. 1003-4.

[31] A.P. Youschkevitch; B.A. Rosenfeld: Al-Kashi; *Dictionary of Scientific Biography*; Edited by C.C. Gillispie; Charles Scribner's Sons; New York; 1974 fwd; vol; 7; pp. 255-62. at p. 255.

[32] J. J O'Connor and E. F Robertson: Arabic Mathematics, a forgotten brilliance; op cit.

[33] E. Rybka: Mouvement des Planetes dans l'Astronomie des Peuples de l'Islam; in *Convegno Internationale: Oriente e occidente Nel Medioevo Filosofia E Scienze;* 9-15 Aprile 1969; Academia Nationale Dei Lincei; Roma; 1971; pp. 579-93; p. 590.

[34] T.Kary-Niyazow: *Astronomitcheskaya chkola Uluhbeka;* Tashkent; 1967; p.268.

after the main initiative in theoretical astronomy had passed to Europe, for example the observatory of Istanbul (1574/5).[36] The Samarkand observatory was a 'monumental' building equipped with a huge meridian, made of masonry,[37] the symbol of the observatory as a long lasting institution.[38] A trench of about 2 metres wide was dug in a hill, along the line of the meridian, and in it was placed the segment of the arc of the instrument. John Greaves writing in 1652, says that according to a trustworthy Turkish astronomer, the radius of that meridian arc was about equal to the height of the dome of the Ayasofya Mosque in Istanbul,[39] thus, approximately fifty metres. Built for solar and planetary observations, it was equipped with the finest instruments available, including a 'Fakhri sextant', with a radius of 40.4 metres, which made it the largest astronomical instrument of its type. The main use of the sextant was to determine the basic constants of astronomy, such as the length of the tropical year. Other instruments included an armillary and an astrolabe. With sophisticated instruments, it was possible to determine at noon every day the meridional height of the sun, its distance from the zenith, and its declination. Uluh Beg also assembled the best-known scientists of his day, over one hundred of them.[40] Among these was al-Kashi, who wrote an elementary encyclopaedia on practical mathematics for astronomers, surveyors, architects, clerks and merchants;[41]and Qadi-Zada who was the head of the madrasa, and who was to succeed al-Kashi at his death.[42]

Observations at Samarkand lasted until nearly 1500 CE (over 75 years).[43] They resulted in 1437 in the Ilkhanide Tables, of which a hundred copies still exist.[44] These tables included some excellent sine and tangent tables as well as improved planetary parameters and star positions.[45] An unusually large number of these were based on original observations rather than on mere updating of Ptolemy or al-Sufi.[46] The star catalogue later aroused much interest in Europe, especially in the early days of serious Arabic studies, in the early seventeenth century.[47] Thanks to the values found in the Zijs (astronomical tables), astronomers could for instance calculate the hour of the rising sun and the altitude of a celestial body.[48] Some astronomical works include tables which allow, thanks to complicated trigonometric formulae, to determine the direction of Mecca.[49] Others allow the expression of the equation of every planet; the tables of Uluh Beg related to the equation of the moon give more than sixty values of the parameter; other data is given by these tables, including the eclipses of the moon and the sun; parallax of a planet, the moon, the sun

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[35] E. Rybka: Mouvement des Planetes; p. 590.
[36] J. North: *The Fontana History of Astronomy and Cosmology*; Fontana press; London; 1994. p. 200.
[37] A Sayili: *The Observatory in Islam;* Turkish Historical Society, Ankara, 1960; p. 271.
[38] A. Sayili: The Observatory, op cit, p. 271.
[39] J. Greaves: Binae Tabule..... pp. 9-10; in A. Sayili; 271.
[40] J.S. Bailly: *Histoire de l'Astronomie Moderne depuis la Fondation de l'Ecole d' Alexandrie* in A. Sayili: The Observatory; op cit; p. 259.
[41] C. A. Ronan: *The Cambridge Illustrated History of the World's Science*: Chapter: The Arabian science, Cambridge University Press. Newness Books, 1983. pp 201-244. at p 223.
[42] Ronan. P. 223.
[43]L. Sedillot, 1853, in Regis Morelon, General survey of Arabic astronomy, encyclopaedia (Rashed ed); vol i, pp 1-19; p 14.
[44] F.Micheau: The Scientific; op cit; P. 1004.
[45] J. North: *The Fontana History of Astronomy; op cit;* p. 200.
[46] J. North: *The Fontana History of Astronomy;* p. 200.
[47] J. North: *The Fontana History of Astronomy;* p. 200.
[48] A. Djebbar: *Une Histoire de la Science Arabe;* Le Seuil; Paris; 2001; pp. 187-8.
[49] A. Djebbar: *Une Histoire de la Science Arabe;* pp. 187-8.

etc.[50] Further findings through observation at Samarkand included the stellar year, found to be 365 days, 6 hours, 10 minutes and 8 seconds, and a star catalogue, containing 1012 stars, was also devised.[51] The observatory at Samarkand was brought down in the upheavals which marked the region. Its remains from 1908 yielded a fragment of the gnomon of large size used to determine the height of the sun from the length of the shadow. There were also remains of a building of cylindrical shape with a complex interior plan.[52] It is also known through the historian Abd-al-Razak that one could see a portrayal of the ten celestial spheres with degrees, minutes, seconds and tenths of seconds, the spheres of rotation, the seven moving planets, the fixed stars and the terrestrial sphere, with climate, mountains, seas, deserts etc.[53] Samarkand, in the early decades of the fifteenth century, Krisciunas observes, was `the astronomical capital of the world.' And for such, `it is deserving of further study.'[54]

Without going into the detail of the article, but just to add to some points already made, Krisciunas reminds us that Uluh Beg is to be remembered not for his princely role, but for his role as patron of astronomy, an astronomer, and observatory builder. His distinction was that he was one of the first to advocate and build permanently mounted astronomical instruments. The importance of his observatory is further enhanced by the large number of astronomers, between sixty and seventy, involved in observation and seminars. Of crucial importance, too, is that observations were carried on a systematic basis for lengthy periods of time, as from 1420 to 1437. The reason, as Krisciunas makes clear, why observations are not completed in one year but instead require ten or fifteen years, is:

> *`the situation is such that there are certain conditions suited to the determination of matters pertaining to the planets, and it is necessary to observe them when these conditions obtain. It is necessary, e.g., to have two eclipses in both of which the eclipsed parts are equal and to the same side, and both these eclipses have to take place near the same node. Likewise, another pair of eclipses conforming to other specifications is needed, and still other cases of a similar nature are required. It is necessary to observe Mercury at a time when it is at its maximum morning elongation and once at its maximum evening elongation, with the addition of certain other conditions, and a similar situation exists for the other planets.'*
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> *`Now, all these circumstances do not obtain within a single year, so that observations cannot be made in one year. It is necessary to wait until the required circumstances obtain and then if there is cloud at the awaited time, the opportunity will be lost and gone for another year or two until the like of it occurs once more. In this manner there is need for ten or fifteen years. One might add that because it takes Saturn 29 years to return to the same position amongst the stars (that being its period of revolution about the Sun), a period of 29 years might have been the projected length of the Samarkand program of observations.'*

[50] A. Djebbar: *Une Histoire de la Science Arabe;* pp.187-8.
[51] D. Abbot ed: *The Biographical Dictionary of Scientists, Astronomers*; F. Muller; London; in B. Hetherington: *A Chronicle of Pre-Telescopic Astronomy*; John Wiley and Sons; Chichester; 1996. p. 191.
[52] F Micheau: The Scientific Institutions in the Medieval Near East, in Encyclopaedia, op cit, vol 3, pp. 985-1007. at pp. 1003-4.
[53] Micheau 1003-4.
[54] Kevin Krisciunas: The Legacy of Uluh Beg; at http://www.ukans.edu/~ibetext/texts/paksoy-2/cam6.html

The Samarkand observatory was headed in turn by two of the greatest Muslim scientists of their generation, also amongst the great figures of Muslim scholarship: Al-Kashi, and Qadi Zada Rumi, whose accomplishments are looked at in turn.

Jamshid al-Kashi

(Born: about 1380 Died: 22 June 1429 in Samarkand, now Uzbekistan)

At the time that al-Kashi was growing up Timur was devastating large regions in the Muslim land, having proclaimed himself sovereign and restorer of the Mongol empire at Samarkand in 1370.[55] While Timur was undertaking his military campaigns, conditions were very difficult with widespread poverty; al-Kashi himself lived in poverty, like so many others at this time. He devoted himself to astronomy and mathematics while moving from town to town.[56] Conditions improved markedly when Shah Rokh took over after his father's Timur death. He brought economic prosperity to the region and strongly supported artistic and intellectual life. With the changing atmosphere, al-Kashi's life also improved markedly.[57]

The first event in al-Kashi's life which we can date accurately is his observation of an eclipse of the moon which he made in Kashan on 2 June 1406 as we know from his Khaqani zij.[58] On 1 March 1407 he completed his treatise *Sullam Al-sama* (The Stairway of Heaven, on Resolution of Difficulties Met by Predecessors in the Determination of Distances and Sizes (of the heavenly bodies).[59] Years later, his *Mukhtasar dar ilm-I-hayat* (Compendium of the Science of Astronomy) written during 1410-11 was dedicated to Sultan Iskander as is indicated in the copy in the British museum.[60] In 1413-14 Al-Kashi finished his Khaqani zij, which he dedicated to Uluh Beg, stating in his introduction how he was working on astronomical problems for a long time whilst living in extreme poverty and that he would not have been able to finish his zij without Uluh Beg's support.[61] In this work there are trigonometric tables giving values of the sine function to four sexagesimal digits for each degree of argument with differences to be added for each minute.[62] There are also tables which give transformations between different coordinate systems on the celestial sphere, in particular allowing ecliptic coordinates to be transformed into equatorial coordinates.[63] The Khaqani Zij also contains detailed tables of the longitudinal motion of the sun, the moon, and the planets. Al-Kashi also gives the tables of the longitudinal and latitudinal parallaxes for certain geographical latitudes, tables of eclipses, and tables of the visibility of the moon.[64]

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[55] For the best biography of al-Kashi see: A.P. Youschkevitch; B.A. Rosenfeld: Al-Kashi; Dictionary of Scientific Biography; op cit; and J. J O'Connor and E. F Robertson: Arabic Mathematics, op cit.
[56] J. J O'Connor and E. F Robertson: Arabic Mathematics.
[57] J. J O'Connor and E. F Robertson: Arabic Mathematics.
[58] A.P. Youschkevitch; B.A. Rosenfeld: Al-Kashi; op cit; at p. 255.
[59] A.P. Youschkevitch; B.A. Rosenfeld: Al-Kashi; p. 255.
[60] A.P. Youschkevitch; B.A. Rosenfeld: Al-Kashi; p. 255.
[61] E.S. Kennedy: *The Planetary Equatorium of Jamshid al-Kashi;* Princeton; 1960; pp. 1-2.
[62] J. J O'Connor and E. F Robertson: Arabic Mathematics; op cit.
[63] J. J O'Connor and E. F Robertson: Arabic Mathematics.
[64] J. J O'Connor and E. F Robertson: Arabic Mathematics.

Al-Kashi was working as a physician to supplement his income until he was secured a permanent livelihood by Uluh Beg.[65] Uluh beg, then, was seeking best scientists to help with his scientific projects. Uluh Beg invited Al-Kashi to join him at this school of learning in Samarkand, as well as around sixty other scientists including Qadi Zada.[66] In his letters to his father, al-Kashi praises the mathematical abilities of Uluh Beg, most particularly his ability to perform difficult mental computations; he described the prince's scientific activity and called him director of the observatory.[67] Despite al-Kashi's ignorance of the correct court behaviour and lack of polished manners, he was highly respected by Uluh Beg.[68] Al-Kashi also gives in his letters interesting information on the construction of the observatory building and its instruments. [69]

Samarqand Madrasa

Al-Kashi remains to this day known for his great mathematical output. He produced his treatise *Risala al-Muhitiya* (Treatise on the Circumference) in July 1424, a work in which he calculated 2 [pi] to nine sexagesimal places and translated this into sixteen decimal places. This was an achievement far beyond anything which had been obtained before, either by the ancient Greeks or by the Chinese (who achieved 6 decimal places in the 5th century). It would be almost 200 years before van Ceulen surpassed Al-Kashi's accuracy with 20 decimal places.[70]Al-Kashi's most impressive mathematical work was, however, *Miftah al-Hisab* (The Key to Arithmetic) which he completed on 2 March 1427. The work is a major text intended to be used in teaching students in Samarkand, in particular al-Kashi aims to give therein the necessary mathematics for those studying astronomy, surveying, architecture, accounting and trading. *The miftah al-Hisab* is divided into five books preceded by an introduction: On the Arithemetic of integrers; On the arithmetic of fractions; On the computation of astronomers (on sexagesimal fractions); On the

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[65] A.P. Youschkevitch; B.A. Rosenfeld: Al-Kashi; p. 255.
[66] J. J O'Connor and E. F Robertson: Arabic Mathematics; op cit.
[67] E.S. Kennedy: A letter of Jamshid al-Kashi to his father; in *Commentarii periodici pontifici Instituti biblici; Orientalia*; ns.29; fasc. 29; 1960; pp. 191-213; p. 200.
[68] J. J O'Connor and E. F Robertson: Arabic Mathematics; op cit.
[69] A.P. Youschkevitch; B.A. Rosenfeld: Al-Kashi; op cit; at p. 256.
[70] A.P. Youschkevitch; B.A. Rosenfeld: Al-Kashi; at p. 256.

measurement of plane figures and bodies; and on the solution of problems by means of algebra (Linear and quadratic equations) and of the rule of two false assumptions etc. [71] The work is described as follows:

> *`In the richness of its contents and in the application of arithmetical and algebraic methods to the solution of various problems, including several geometric ones, and in the clarity and elegance of exposition, this voluminous textbook is one of the best in the whole of medieval literature; it attests to both the author's erudition and his pedagogical ability.*[72]

Because of its high quality, this work was frequently copied, and served as a manual for hundreds of years.[73] Dold-Samplonius has discussed several aspects of al-Kashi's Key to Arithmetic.[74] For example the measurement of the muqarnas refers to a type of decoration used to hide the edges and joints in buildings such as mosques and palaces. The decoration resembles a stalactite and consists of three-dimensional polygons, some with plane surfaces, and some with curved surfaces. Al-Kashi uses decimal fractions in calculating the total surface area of types of muqarnas. The qubba is the dome of a funerary monument for a famous person. Al-Kashi finds good methods to approximate the surface area and the volume of the shell forming the dome of the qubba.[75]

Al-Kashi's great mathematical achievements are also *Risala al-muhitiyya* and *Risala al-watar wa'l jaib*; both written in direct connection with astronomical researches and especially in connection with the increased demands for more precise trigonometric tables.[76] When he died, in 1429, al-Kashi was very much mourned, not least by Uluh Beg.[77]

Qadi Zada al-Rumi (or more properly Salah eddin Musa pasha)

(Born: 1364 in Bursa, Turkey; Died: 1436 in Samarkand, Uzbekistan).[78]

Montucla, in his history of mathematics holds that he was a Greek convert to Islam which Dilgan suggests may come from a misunderstanding of the name al-Rumi, as the peoples who lived in Asia Minor were called Rum, meaning Roman (not Greek), because Asia Minor was once Roman.[79]Qadi Zada means "son of the judge" and we must assume that indeed Qadi Zada's father was the judge.[80]

It was in his home town of Bursa that Qadi Zada was brought up, and completed his standard education and then studied geometry and astronomy with the theologian-encyclopaedist al-Fanari (1350-1431).[81] His teacher al-Fanari realised that Qadi Zada was a young man with great abilities in mathematics and astronomy and he advised him to visit the cultural centres of the empire, Khorasan or Transoxania, where

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[71] A.P. Youschkevitch; B.A. Rosenfeld: Al-Kashi; pp. 256-7.
[72] Kary Niyazov: *Astronomischeskaya shkola Ulugbeka*; 2nd edition; Tashkent; 1967; pp. 141-2.
[73] A.P. Youschkevitch; B.A. Rosenfeld: Al-Kashi; op cit; at p. 256.
[74]In J. J O'Connor and E. F Robertson: Arabic Mathematics; op cit.
[75] In J. J O'Connor and E. F Robertson: Arabic Mathematics.
[76] A.P. Youschkevitch; B.A. Rosenfeld: Al-Kashi; at p. 257.
[77]C.A. Ronan: Arabian science; op cit; p 223.
[78] H. Dilgan: Qadi Zada al-Rumi; *Dictionary of Scientific Biography*; op cit vol 11; pp. 227-9; at p. 227.
[79] H. Dilgan: Qadi Zada al-Rumi; at p. 227.
[80] J. J O'Connor and E F Robertson: Arabic Mathematics; op cit.
[81] H. Dilgan: Qadi Zada al-Rumi; op cit; pp. 227-9; at p. 227.

he could benefit from coming into contact with the top mathematicians of his time.[82] He also gave him letters of recommendation and one of his works: *Emmuzeg al-ulum* (Types of sciences) to present to the scholars of those parts.[83] Following this, Qadi Zada studied Mathematics and astronomy in Transoxiana; then a great cultural centre. In 1383, already, Qadi Zada gained a great reputation as a mathematician by completing a treatise on arithmetic: *Risala fi'l Hisab;* a work which covers arithmetic, algebra and mensuration.[84]

After visiting a number of cities, Qadi Zada reached Samarkand in about 1410. Uluh Beg was only 17 years old when Qadi Zada met him at Samarkand in that year 1410.[85] He was far more interested in science and culture than in politics or military conquest but he was, nevertheless, deputy ruler of the whole empire and, in particular, sole ruler of the Mawaraunnahr region. [86] Qadi Zada had frequently Uluh Beg as a student at his classes.[87] Meeting Uluh Beg was certainly a turning point for Qadi Zada, for he would spend the rest of his life working in Samarkand. Qadi Zada wrote a number of commentaries on works on mathematics and astronomy during his first years in Samarkand, which seem to have been written for Uluh Beg and it would appear that Qadi Zada was producing material as a teacher of the brilliant young mathematician.[88] One commentary on the compendium of the astronomer al-Jaghmini was written by Qadi Zada in 1412-13, while a second commentary was on a work by al-Samarkandi.

In 1417, perhaps encouraged by Qadi Zada, Ulugh Beg began building a madrasa. The madrasa, fronting the Rigestan Square in Samarkand, was completed in 1420 and Uluh Beg then began to appoint the best scientists he could find to teaching positions in his university. [89] There is little doubt that al-Kashi, Qadi Zada and Uluh Beg himself, were the leading astronomers and mathematicians at this prestigious establishment in Samarkand.[90]

Construction of the Samarkand observatory began in 1424 and, while the observatory was under construction, al-Kashi wrote to his father, praising the mathematical abilities of Uluh Beg and Qadi Zada. Qadi Zada's most original work *Risalat al jayb* (Treatise on the Sine) [91] was a computation of sines with remarkable accuracy. He published his methods in his treatise in the sine and, although al-Kashi also produced a method for solving this problem, the two methods are different and show that two remarkable scientists were both working on the same problems at Samarkand; Qadi Zada computed the sine of angles to an accuracy of 10-12 significant figures (if expressed in decimals), as did al-Kashi.[92]

After the death of al-Kashi, Qadi Zada became the director of the Samarkand observatory. The major work undertaken at the Observatory in Samarkand was the production of the catalogue of the stars, this star

[82] J. J O'Connor and E.F Robertson: Arabic Mathematics, a forgotten brilliance; op cit.
[83] H. Dilgan: Qadi Zada al-Rumi; op cit; at p. 227.
[84] H. Dilgan: Qadi Zada al-Rumi; p. 227.
[85] J. J O'Connor and E.F Robertson: Arabic Mathematics, a forgotten brilliance; op cit.
[86] J. J O'Connor and E.F Robertson: Arabic Mathematics, a forgotten brilliance; op cit.
[87] H. Dilgan: Qadi Zada al-Rumi; at p. 227.
[88] J. J O'Connor and E.F Robertson: Arabic Mathematics, a forgotten brilliance; op cit.
[89] J. J O'Connor and E.F Robertson: Arabic Mathematics, a forgotten brilliance; op cit.
[90] J. J O'Connor and E.F Robertson: Arabic Mathematics, a forgotten brilliance; op cit.
[91] H. Dilgan: Qadi Zada al-Rumi; op cit; at p. 227.
[92] J. J O'Connor and E.F Robertson: Arabic Mathematics, a forgotten brilliance; op cit.

catalogue, the Zij-i Sultani, set the standard for such works up to the seventeenth century. Published in 1437, in the year following Qadi Zada's death, it gives the positions of 992 stars. [93] The catalogue was a collaborative effort by a number of scientists working at the Observatory but the principal contributors were certainly Uluh Beg, al-Kashi, and Qadi Zada. In addition to tables of observations made at the Observatory the work contained calendar calculations and results in trigonometry. [94]

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