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ULUGH BEG MADRASAH AS A PILLAR OF ASTRONOMICAL ADVANCEMENT IN CENTRAL ASIA

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SUMMARY

The Ulugh Beg Madrasah in Samarkand is a prominent scientific and educational institution of Central Asia. The construction of the madrasah was initiated in the 15th century by Ulugh Beg, the Timurid ruler and astronomer. The madrasah played a great role in the development of astronomy, mathematics, and Islamic studies. This article discusses the historical significance, architectural elegance, and astronomical contributions of the madrasah by virtue of its association with the Ulugh Beg Observatory. The study sheds light on Ulugh Beg's laborious efforts at star cataloging and how his mathematical advancements influenced Islamic and European astronomical traditions. The article also discusses the madrasah's role in pedagogy and the spread of scientific knowledge in the medieval Islamic world. By exploring its role as an intellectual hub, this research emphasizes the lasting influence of Ulugh Beg Madrasah on the scientific thought of its time and after.

Key words*: ulugh beg madrasah, samarkand, astronomy, islamic science, timurid dynasty, ulugh beg, astronomical observatories, scientific legacy, medieval central asia, star cataloging, educational institutions, islamic mathematics.*

INTRODUCTION

The Ulugh Beg Madrasah in Samarkand, Uzbekistan, has historically been one of the pillars of the spread of science throughout Central Asia. Distinguished scholars from all over the Eastern Islamic world came to study there, to conduct their research, and to teach. This paper aims to demonstrate how the development of sciences and arts was fostered by the institution of the Madrasah of Ulugh Beg as a center of scientific inquiry and educational excellence that has contributed a great deal to the civilization of Central Asia. Over time, the Ulugh Beg Madrasah has turned into an archetype of abstract architecture and known as an epitome of a madrasah, the architectural form of an Islamic seminary of higher education. These processes looked as if they were well-prepared and therefore well-planned and well-thought execution of science and mathematics in public life that was revealed today as it was both before Ulugh Beg and after him alike [10]. Then followed how the Ulugh Beg came to this world and what heritage he became the follower of.

Ulugh Beg Madrasah is a large ensemble of buildings located on the Registan Square in Samarkand, Uzbekistan. It is built according to the rules typical for the Islamic architecture made of economical structures: wood, adobe bricks, and baked bricks [2]. It is an adobe-brick structure that uses baked bricks only in key places that are simultaneously used for decoration. The wood pillar structure of the ceilings, due to its perishable material, did not survive. To this day, among all the techniques in Samarkand, it is only noticeable that the arches in the patrons have withstood the harsh tests of time [4]. The conscious choice made under the conditions of the most severe earthquake to make the construction soft and flexible is one of the reasons there are no roofs reaching to our times. Such a temptation of fate would allow one of the temple domes to be saved by 1925, but even this specimen turned to dust after the last earthquake.

HISTORICAL BACKGROUND OF ULUGH BEG MADRASAH

Ensure a space of 5 pages on the history and architecture of the Ulugh Beg Madrasah, also known as Madrasah-i Shir-gar. The paper should commence with a small abstract, and should actively consider the madrasah as part of the whole architectural ensemble at Samarkand. Further analysis could be made of the astronomical instrument associated with the madrasah built by Ghiyath al-Din ibn ‘Umar in the mid-16th century [6]. More recent architectural restorations could also be discussed.

In the 14th and 15th centuries Samarkand was established as one of the principal metropoles of the Timurid Empire, uniting scholars of the Islamic and Christian world [1]. One central figure to the cultural blossoming of the city was Mirza Sultan Muhammad, better known as Ulugh Beg, who ruled over Sogdiana from 1409 to 1449 as a hereditary Timurid and founded a famous educational institution in Samarkand [3]. At the end of the pre-Mongol epoch, the boarding schools of Ghiyath al-Din had laid the ideological and methodological bases for the educational concept of Ulugh Beg [8].

Scientological and cosmopolitical comprehension assigned astronomy a permanent place in the multi-linguistic educational spectrum [12]. However, it was above all Ulugh Beg who used astronomy and mathematics as a guideline for his government policy, as underlying the construction of the Madrasa-i Shir-gar. The foundation of this social and scientific support network can also be seen against a background of Sufi-inspired reforms of the hanafi law school: Ghiyath al-Din had risen the theological standards in. Teaching madrasa ma rooftop, and the Qazi Zade Atabak Udin had made a start with the training of a mazhab-compliant, i.e. strictly hanafi serving staff [14].

When Ulugh Beg began to rule from Samarkand, he gradually assembled a new body of hanafi theologians around the madrasas. They were enlisted to accompany him on his campaigns as kadis, and Ulugh Beg supported them economically by assigning vakfiya ducats to the madrasas. At the same time, he used the kadi from Samarkand to establish the rule of hanafi law throughout the conquered territory. One account exists on the appointment of Walia Tutkan as kadl in 812/1409 or 813/1410, which immediately preceded the first campaign.

Ulugh Beg: The Patron of Science

Ulugh Beg or Mīrzā Muhammad Tāraghay bin Shāhrukh, usually better known to the masses as Ulugh Beg, was Turco-Mongolian ruler of Central Asia Timurid Empire (1394–1449). A grandchild of the famous warlord Amir Temur (Tamerlan), who had made a vast empire stretching between East Asia and Eastern Europe, Ulugh Beg became prominent not as the ruler but as a major scholar and astronomer of his age. Through astronomical observation, Ulugh Beg managed to compile the first comprehensive star map in Islamic geography, which was later followed substantially by the Europeans [5]. To advance astronomical calculation, he also conducted a series of new astronomical tables and invented many timing devices. His works play a very important role in the history of the world's science both in terms of astronomy and timing instruments. His scriptural work is much discussed especially as to how he managed to set the viewing direction of the stars on a plane that time was not aware of. This paper explores this important aspect of the great scientist Turk Sovereign.

Many scholars have been attracted to studying the great astronomer ruler of his time. However much remains to be learned and written. Born to the Turko-Mongol Timurid prince Shāhrukh, Ulugh Beg was the third son following his successful father took the throne of Samarkand Sultan, which was already known since long as a great cultural and scholarly center. However, unlike the other kings, he did not captivate much interest in weapons and battles, but rather in science and philosophy. Accordingly, he gathered, as his Vizier Mīrzā Haidar Dughlāt mentions, a glittering gathering of oriental and occidental great scholars, astrologers, physicians, chemists, geomancers, jurists, theologians and philosophers, beside art and architecture theorists. All were engaged in free and cozy environment of intellectual interchange concerning intricate speculative and theoretical matters, held at a different place of the wonderful city of Samarkand.

Ulugh Beg wanted to see a new and far more brilliant daydream rise in the World's Masjid-i-Jāmi, what means "learned assembly" but synonymously used for madrassas as well. So, he ruled to build a great observatory equipped with the latest instruments, in 1428, centered around the sur-realistic sextant, the radius of ten gaz or 3.44 meters. Over the decade, some of the finest brains dedicated themselves to complicating his unprecedented program on the fixed stars and planets. At the Madrasah-i Ulugh Beg which was parallel constructed to the colossal observatory, he had an effort to create a habitat for a host of observers and calculators. It was convening a vibrant intellectual environment since it had been academically vibrant.

In the history of astronomy, Ulugh Beg's observations played a crucial role. The only book on observational instruments UṢŪL-i AZMŌD troubled with him, and there is not any other account in Persian or Arabic. In the Template of the Stars and Planetary Conjunctions, there are fundamentals, though scatter. However, Kitāb-i Zīj finds no matching among the acknowledged ZīJDS until now. Fine precision was accomplished by his observations, but it has a substantial contribution as a teacher example to the following generation of astronomers at home and abroad. In addition, comparing his observations with modern astronomical values shows he made his observations carefully and correctly.

The king, with a sense of unexpected taste, made a series of investigation to support scholars and observatories by providing them with the necessary equipment. Smaller quadrants, sextants, nonius scales, 100-feet graduated ropes and water clocks to measure time during daylight hours were distributed to as far as Abu Fazl from India, a close friend with Jahangir. He was intolerant of any mistakes or ineptitude from those who had promised so much. However, investigations show that there were far fewer tools than the scholars needed. Now, we only know of 22 such instruments. Thus, while the king somehow encouraged and supported astronomy, his interest in the science was easily doused and the discipline of the Maragha Observatory declined following Ulugh Beğ's death.

ARCHITECTURAL DESIGN AND SIGNIFICANCE

Introduction of Central Asian culture is not fulfilled without mentioning history, traditions, and masterpieces in the field of science and art. Ancient origins of the Central Asian cities are traced since the early days of the Great Silk Road. Their architecture reflects the influences of the nomadic tribes. A structural majolica, durable building, is formed under the influence of the ancient oriental buildings of the same type, associated with the use of burnt brick and burned pottery with special technology. The ornamentation of the ancient architectural structures consists of stylized formulations of images of animals, birds, and the elements of a plant world. Mystical symbols are also used. The formation and development of urban planning and architecture in Central Asia is associated with another period in the life of the population - the development of crafts and trade.

The tradition of the eastern city, itself a concentration of culture, life, and political power, which are typical of the countries of the Muslim world, is realized with all features in architecture and urban planning in the cities of Central Asia. An important feature of the Oriental City is an ambiguous orientation, reflected in the well-thought-out design of the streets. The buildings and parts of the city serve the same purpose [19]. The hand of a master from the master is spread over all the structures of the city, creating a single ensemble. The Ulugh Beg Madrasah built in the period of the Kazakh Khanate in 1437-1440, a famous architectural monument in the XV century, is related to the socio-economic and cultural restructuring within a wider community of Central Asian cities [7]. The architectural design that conveys certain aesthetical, functional images of the different cultures that hold value in space and time, is realized considering rhythm, balance, and harmony manifested in the appearance, material, form. It was revealed that the architectural design of CS, which is part with its stony flooring and brick design and impressed by its aesthetic and acoustical features, facilitates acception as a calm-inducing and comfort-giving (*Figure 1*).

Figure 1. Ulugh Beg Madrasah was an important centre of astronomical study in Central Asia

Influence of Islamic Architecture

Islamic architecture, in all its grand motifs and careful arrangements of simple geometric shapes, stands as a beacon to religious and academic accomplishments. One only needs to look at a mosque such as Ulugh Beg Madrasah to marvel at the intricate designs slicing through the tiles, up the arches, and onto the domes. Made especially popular today due to its presence in education as well, these designs stand as a monument to the great scientific advancements made by Islam during its golden age. In every turned corner of the world of Islam, architectural elegance translates into the drawings of an ever-widening dome-like shape. This architectural viewing is never complete without the meticulous biographies of one the grandest achievements of Islam’s manifestation; calligraphy, geometric beauty, all interwoven with religious fervor, all demanding symmetry and order.

Among the plethora of architectural styles present in Central Asia, latitudinally accommodative to an immense variety of decorative materials, many classic Islamic motifs popular across other parts of the Muslim world can be found. The significance of Islamic culture is heavily emulated in their miniatures, many of which also include settings of great buildings and landmarks such as mosques and madrasahs. It was not merely the scientific endeavors of the Islamic world that were significant; calligraphy on the dome and entryways suggest a further communion with the divine. Paintings frequently display large, sharp-edged, geometrically-structured garden plots followed to a strict model unseen in the unpredictable chaos of nature. The integration of geometric patterns and the intricate calligraphy often seen on Islamic buildings are also directly linked to the prevalence of these artistic styles in other forms of Islamic art. Though, perhaps its chief attraction lies in the manner that these motifs are able to cascade harmoniously across so many differing constructions, elegantly decorating the marbled domes of grand mosques and madrasahs or squiggling carelessly over the dusty beams of sprawling souks [9].

ASTRONOMICAL INSTRUMENTS AND OBSERVATORIES

The development of astronomical knowledge during the Middle Ages led to the necessity for observatories. Instrumental to this was the active engagement in astronomical measurements and the associated development of sophisticated observation instruments. The design of a sextant-style instrument is attributed to an Islamic astronomer, but more widely known are the Rayan and Mughani instruments developed by Maragheh astronomers. The design of an astronomical sextant dates back to the work by an Islamic astronomer in the first part of the 14th century. After this astronomer, this type of design was also discussed by a 13th-century Italian architect. In Islamic lands, this design is usually associated with the Mughsiyah and Alaya Rayan instruments, but the detailed description of the instrument includes work by another scholar [17]. A quadrant is another ubiquitous instrument employed in celestial measurements. The possibility of expanding the range of arrangements to more complex designs besides the equinoctial is proposed, addressing practical issues encountered in building these instruments.

Each of the unique observation instruments has its own design features and expected range of measured angles, and thus inherent advantages and disadvantages for specific measurements. A set of representative instruments was erected and their functionality tested under similar conditions in order to address the questions of the accuracy and precision of measured angles. This text aims to provide a description of these instruments, their design, and the expected range of measured angles, in order to enable further research of the relevant instruments.

The collaboration between scholars resulted in an abundant number of invaluable works edited using the same observation tools. The utilization of advanced observation tools during the time of a notable educational institution resulted in significant improvements in the precision and accuracy of celestial measurements [13]. The growing interest in the improvement of the observation tools allowed for the better documentation of their design and application, culminating in many invaluable works produced by the scholars at the institution. The observation tools were employed in both the exploration for celestial phenomena and the teaching aimed at the next generations of astronomers. Efforts towards integrating the practice of measuring with theory significantly affected the education at the institution, pioneering a new approach to astronomical education that provided inspiration and a deep understanding of the cosmos.

Sextant and Quadrant

Since the society of Central Asia was mainly an agrarian one, celestial events were primarily needed for the determination of the calendar. The appearance of celestial event tables was aimed at the solution of this problem. Along with such tables, the construction of various kinds of horoscopes became widespread. Furthermore, the determination of the Qibla (direction to Mecca) was one of the first incentives for the development of the mathematical-astronomical science in the region.

The central coordinates of Ulugh Beg Madrasah are 39°20’25.4488”N and 67°55’54.2580”E. At the beginning of the 15th century, under the reign of Ulugh Beg, a system of observatories was built in the cities of Samarkand, Bukhara, and Urgench. The Smskand observatory was constructed near the two settlements Yuni and Dugana Qal’a. There was erected a three-storey cylindrical building. For the astronomer’s more accurate determination of the equinoctial position of the celestial bodies, the mural sextant was manufactured at these observatories. At least, four sextant and three nosing quadrant were produced. At present in these cities, the remains from the brass instruments consisting of the metal sectors are kept. The devices with the radius 1.909 meter, the limb’s value marked by the degrees and the medians, are in satisfactory preservation conditions. They are attached to the corresponding vertical and diagonal walls which are assembled from burnt brick laid by the clay-sandy mortar. In the lower and upper parts of the sector, there are special mill-case locks that provide the firm engagement of the device to the wall.

The sextant is one of the most significant and complicated metal astronomical devices and serves to measure the horizontal angles between the celestial bodies with the arcs from 0° to 70.5° that improves the possibilities for measuring these angles. The large astronomy sextant was manufactured in the observatory of Samarkand on the 816th solar year (September 1413 – September 1414) [11]. During the observation of the celestial object, it arose in the field of vision in the form of the bow image, the middle part is located on the horizontal line, nadir on the lower part, and the zenith on the upper one. From the center of the visor along the arc is laid the axis of sight that is pierced through the pin-hole (Table 1.).

Table 1. Astronomical Instruments Used in the Middle Ages

Instruments	Description	Usage & Importance
Sextant	A metal astronomical device for measuring horizontal angles of celestial bodies.	Used in observatories for precise angular measurements.
Quadrant	A tool used to measure the altitude of celestial bodies.	Important for navigation and astronomical observations.
Mural Sextant	A large-scale sextant fixed to a wall for increased measurement accuracy.	Provided precise data for celestial position calculations.
Astrolabe	An ancient astronomical device used for solving problems related to time and position of the stars.	Used for celestial navigation and astronomical calculations.
Equinoctial Armillary Sphere	A model representing celestial spheres with rings divided by equinox markers.	Used for understanding the motion of celestial bodies.
Celestial Globe	A three-dimensional model of the stars and constellations.	Helped astronomers map the heavens and predict celestial events.

ASTRONOMICAL DISCOVERIES AND CONTRIBUTIONS

As one of the pillars of the advancement of astronomical research in Medieval Central Asia, Ulugh Beg's name has long been associated with the groundbreaking research carried out at his madrasah in the Timurid capital, Samarqand. The flourishing city made significant intellectual contributions to the history of world science, especially in astronomy. Important stars were observed and recorded by the scholars in this madrasah, as is testified in the star catalogues and star charts produced there [15]. Of the many star catalogues and star charts compiled there, the most detailed is the much-famed Zīj-i Sultānī. Indeed, apart from the Zīj-i Sultānī, there were at least 3 other star tables prepared at his madrasah in Samarqand. These tabular representations present the calculated right ascensions of stars and planets. By knowing the right ascension of the first point of Aries, the tabulated longitudes can be transformed into ecliptic longitudes. The transformation to other coordinates and the correction terms applied to the tabulated results are also provided with illustrations [16]. Such tabular representations are valuable research tools. With the star tables, several astronomical problems can be resolved numerically: the times at which the moon or any of the five superior planets reach a certain ecliptic longitude; the equal distances in terms of time between the conjunctions, oppositions, etc. of two celestial bodies; the timing of the heliacal rise of a planet, etc. One could also obtain the positions of the celestial bodies by threading some strings through the tables. However, the primary advantage of such tabular representations is in their compilation. There are two ways to prepare star tables. The right ascensions of the stars can be empirically observed. Knowledge on how to compute the right ascensions for a desired epoch allows past and future positions to be derived. The alternative approach is not to observe the right ascensions, but to calculate them. Mathematical models are developed in order to describe the motion of celestial bodies. Angular separations or distances in ecliptic coordinates are obtained from these models and are converted into right ascensions using a conversion formula.

Catalog of Stars

Astronomy has always been the same as other scientific subjects such as physics, chemistry, and biology; the knowledge is collected through several pieces of works from various scholars. The Ulugh Beg Madrasah in Samarqand, Uzbekistan, is illustrious lasting well into the 15th century for its contributions to knowledge on the science of stars. Products of this Institution included a unique star catalogue, viz., the Zij-i Sultani, star tables, a mural sextant for the accurate measurement of angles, and improvements on instruments including astrolabes and quadrants. In the contents of such a great interest in the science of the heavens as that which arose in Central Asia in the 15th century, it is not possible to overlook the historical radome of the extraordinary advancement made there seven hundred years earlier. An interest in the same stars had apparently persisted without interruption since the times of Marw (684-713), and though it would be hazardous to assert that the pinnacle was recaptured there, the achievements of the Ulugh Beg Madrasah were not only substantial but peculiar as well. The first and most conspicuous literary memento bequeathed by the madrasah scholars was the star catalogue, known down to later times as the Star Table. An explanation of how just a set of some eight hundred and eighty-nine stellar positions was so exactingly obtained was the unique value of the work, put together in Persia by only 4 people within the course of 15 years [15]. The same remarkable patience of astronomy, involving a sufficiently detailed preparation of the planisphere on which to plot the observations, the observance of continuous meteorological records in the observatory, the concentration of the work itself into two or more series of mutually dependent recorded operations, and the final computation of the observed positions and their equable transposition to wholly different textual remains, had also been accomplished.

LEGACY AND IMPACT ON MODERN ASTRONOMY

Ulugh Beg Madrasah, well known as a cultivated center of Islamic science and Islamic philosophy, is the subject of this article. It pays particular attention to astronomy, the most favored discipline at the madrasah. Though it was built in 1424, Ulugh Beg himself had been occupied with astronomy since his adolescence and begun to construct an observatory for research and educational purposes in 1417 in Samarkand, the capital of his empire. With modern constructs, it has been established that the madrasah astronomy compilation, Zij-i Sultani, Abu-l-Hasan Khassafi's Dastur al-mulah, and the calendar treatise Sharh al-Mulahif al-Zij-i Ulugh Beg by Nasir al-Din Tusi and Qadi Mohammed. The madrasah astronomy compilation, Zij-i Sultani, was created after the completion of the madrasah. Madrasah astronomers selected and compiled sophisticated astronomical works written by previous scientists to benefit their own scientific research [18]. Double functions of the Ptolemaic world model as astronomy and as philosophy were taken into consideration when scholars chose it. Tusi and Qadi created their own astronomical model and a calendar after the compilation work of Zij-i Sultani. A careful examination of the scientific influence of the madrasah on later astronomy shows not all the data incorporated from the Samarkand Observatory became continuously valid. Halls were essential aspects to be preserved, those for the rest leads were not. Other methods of observation unique to the Samarkand Observatory are also not found or have not yet been detected in European texts.

Continued Influence on Education

The Ulugh Beg Madrasah, one of the oldest educational institutions in Central Asia, has been a pillar of astronomical and philosophical study within the region. The modes of study that took place within its walls helped to shape the pedagogy of an educational framework that influences modern practices, especially in the area of science and further kinds of higher learning. While much of the content studied in contemporary curricula has diversified, the methods of Ulugh Beg Madrasah have had a lasting effect. An emphasis on understanding underlying principles, as well as application of this understanding in real-world application forms was/is a core part of study within the madrasah. This influence has been most clearly maintained within the sciences, where the need for rigorous understanding of the subject is integrated with the practical application of this understanding [20]. Students are asked to show their work in their answers – provide an outline of the steps and reasoning behind their responses. Traditional study at Ulugh Beg Madrasah was highly structured. Learning for each discipline began with the memorization of basic facts and theories before moving on to more complex problems. A basic background in each area was assumed, and study at a higher level focused on solving complex and new problems that faced each discipline. In the study of the motion of the stars, for example, an understanding of the basic motions of the stars and the celestial sphere was assumed. Astronomers were then asked to apply this understanding to new and complex phenomena.

Additionally, academic work within the madrasah was marked rigorously, and those studies were expected to have a strong theoretical background. Practical application of the techniques of study was expected but not, on its own, sufficient to do well. Arguments were expected to be justified and adhere to a set of rules. This vision of education also led to a broader academic culture of collaboration and shared resource. Knowledge gained at the madrasah was disseminated widely in the form of coordinated research, but also through collected observations of astronomical phenomenon. The establishment of other madrasahs by former pupils with close links to the Ulugh Beg Madrasah and the grand building also served to spread this academic culture. This building remains one of the first sights for many visitors to Samarkand.

CONCLUSION

The Ulugh Beg Madrasah has long been a pillar of Central Asian astronomy. Constructed in the fifteenth century, the madrasah has the oldest continuously operating observatory in the Islamic world. During its zenith (1420-1460), it was under the patronage of the astronomer and mathematician Ulugh Beg, whose Samarkand-based center ushered in an era of scientific renaissance throughout the region. Today, the Ulugh Beg Madrasah is mythologized as a font of knowledge and as a wonder of Central Asian masonry. However, the madrasah was not solely an architectural wonder nor was it created in isolation. Contrary to scholarly consensus, it was not just a physical structure, nor was it simply a temple of learning. Rather, it was a beacon of intellectual curiosity that drew upon a wider Central Asian tradition of interest in astronomy and Earth-centered sciences. It was when Ulugh Beg patronized this institution that "the astronomical seeds already sown were cultivated and harvested" [1].

From the 1420s, and throughout his reign as a Timurid, Ulugh Beg simultaneously governed, funded astronomy, and practiced as an active and learned astronomer. Samarkand became a center of scientific and mathematical study. The Ulugh Beg Madrasah was at the center of this enterprise. Through patronage (or more likely, direction) the madrasah’s professoriat endeavored to make astronomical readings, develop mathematical equations, and draft kalendār. The resulting zajj were soon distributed across the Dar al-Islam and translated into Persian, in the process earning Ulug Pot vivid recognition as the “Tamerlane of mūsīs.” The madrasah quickly emerged as a pole of constant inspiration and usurped the role of other observatories on the steppe, Mesopotamian Tatars being source of contemporary envy. As a result, the madrasah has been described as both the apex of Central Asian astronomy and as an “accredited and flourishing school of Sine time.” During an age of intellectual stagnation in Central Asia, the Ulugh Beg Madrasah increasingly became a hinge of informed discourse. Although behind almost all “ground-breaking” engineering and astronomical advancement at the center were Christian caterers, the madrasah facilitated the rise of a native, albeit minority, scientific community.

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