

THE PLACE OF ASTRONOMICAL DECORATIONS IN ARCHITECTURAL MONUMENTS

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Annotatsiya: Ushbu tadqiqot O'rta Osiyoning qadimiy me'moriy yodgorliklarida astronomik bilimlarning dekorativ san'atdagi namoyon bo'lishini kompleks o'rganishga bag'ishlangan. Tadqiqot davomida XIV-XVII asrlarga oid 45 ta me'moriy yodgorlik tahlil qilindi, ularning orasida Samarqand, Buxoro va Xiva'dagi muhim masjid, madrasa va maqbaralar mavjud. Tahlil natijalari shuni ko'rsatdiki, astronomik bezaklarning 73% i muqarnas elementlarida, 62% i gumbaz ichki bezatishlarida va 58% i portal yuzalarida uchraydi. Quyosh, oy, yulduzlar va burjlar tasvirlari nafaqat estetik, balki ilmiy-astrologik ahamiyatga ega bo'lgan. Tadqiqot me'morchilik va astronomiya o'rtasidagi chuqur bog'liqlikni, shuningdek, O'rta Osiyodagi ilmiy maktablarning me'moriy san'atga ta'sirini aniqladi. Natijalar me'moriy yodgorliklarni restavratsiya qilish va ilmiy-madaniy merosni saqlashda qo'llanilishi mumkin.

Kalit so'zlar: me'moriy yodgorliklar, astronomik bezaklar, muqarnas, islom me'morchiligi, dekorativ san'at, burjlar tasviri, O'rta Osiyo me'morchiligi.

Аннотация: Данное исследование посвящено всестороннему изучению проявления астрономических знаний в декоративном искусстве древних архитектурных памятников Центральной Азии. В ходе исследования были проанализированы 45 архитектурных памятников XIV-XVII веков, среди которых важные мечети, медресе и мавзолеи Самарканда, Бухары и Хивы. Результаты анализа показали, что 73% астрономических орнаментов встречаются в элементах мукарнаса, 62% — во внутренней отделке куполов и 58% — на поверхностях порталов. Изображения солнца, луны, звезд и созвездий имели не только эстетическое, но и научное и астрологическое значение. Исследование выявило глубокую связь между архитектурой и астрономией, а также влияние научных школ Центральной Азии на архитектурное искусство. Результаты могут быть использованы при реставрации архитектурных памятников и сохранении научно-культурного наследия.

Ключевые слова: архитектурные памятники, астрономические украшения, мукарны, исламская архитектура, декоративно-прикладное искусство, изображение созвездий, архитектура Центральной Азии.

Abstract: This study is devoted to a comprehensive study of the manifestation of astronomical knowledge in decorative art in the ancient architectural monuments of Central Asia. During the study, 45 architectural monuments of the XIV-XVII centuries were analyzed, among which there are important mosques, madrasas and mausoleums in Samarkand, Bukhara and Khiva. The results of the analysis showed that 73% of astronomical ornaments are found in muqarnas elements, 62% in the interior decoration of domes and 58% on the surfaces of portals. The images of the sun, moon, stars and constellations had not only

aesthetic, but also scientific and astrological significance. The study revealed a deep connection between architecture and astronomy, as well as the influence of scientific schools in Central Asia on architectural art. The results can be used in the restoration of architectural monuments and the preservation of scientific and cultural heritage.

Keywords: *architectural monuments, astronomical decorations, muqarnas, Islamic architecture, decorative arts, depiction of constellations, Central Asian architecture.*

INTRODUCTION

The Islamic architecture of Central Asia occupies a special place in world culture not only as a model of beauty, but also as a harmonious system of science and art. In the 14th-17th centuries, astronomy reached a high level in the scientific centers of Central Asia, and this development was reflected in architectural art [Pugachenkova, 1979, 156-178]. The Ulugbek Observatory in Samarkand, the madrasas in Bukhara and Khiva are examples of the manifestation of astronomical knowledge in architectural decoration.

Astronomical elements in architectural monuments were not only decorative, but also an important component that reflected scientific knowledge, helped determine the direction of the qibla, and expressed religious and philosophical ideas [Bulatov, 1978, 89-112]. The work of such great scholars as Ulugbek, Ali Qushchi, Abu Rayhan Beruni had a great influence on the art of architecture.

The relevance of the research is determined by the following: - The need for a comprehensive study of the architectural heritage of Central Asia - Scientific substantiation of the connection between astronomy and architecture - Creation of a theoretical basis for restoration work - Preservation and promotion of the national cultural heritage

The purpose of the research is a comprehensive analysis of the role, significance and scientific foundations of astronomical ornaments in the Islamic architectural monuments of Central Asia.

Research objectives: 1. Systematic classification of astronomical ornaments in architectural monuments 2. Determination of the regularities of the location of astronomical elements 3. Study of the relationship between ornaments and astronomical knowledge 4. Historical evolution of architectural-astronomical relations

Object of research: Architectural monuments of Central Asia of the XIV-XVII centuries (Samarkand, Bukhara, Khiva).

Subject of research: Scientific and aesthetic characteristics of astronomical signs, symbols and ornaments in architectural monuments.

LITERATURE ANALYSIS AND METHODS

Literature analysis

Fundamental work on the study of Central Asian architecture was carried out by G.A. Pugachenkova. In her work "Masterpieces of Architecture of Central Asia", a thorough analysis of the role of astronomical elements in architectural composition was carried out [Pugachenkova, 1979]. The author emphasizes the reflection of astronomical knowledge in muqarnas ornaments.

M.S. Bulatov in his monograph "Geometricheskaya harmonizatsiya v arkhitekture Sredney Azii" mathematically substantiates the connection between architectural proportions and astronomical calculations [Bulatov, 1978]. He proved the connection of the dimensions of the dome and portal with astronomical cycles.

B.A. Rozenfeld and A.P. Yushkevich in their work "Geometry and Astronomy in the Countries of Islam" show the convergence of geometry and astronomy in the Islamic world [Rozenfeld and Yushkevich, 1983, 234-267]. They analyzed the methods of projection of the celestial sphere in architectural decorations.

L.Yu. Mankovskaya studied the symbolic system in Central Asian architecture and showed the importance of solar and lunar symbols in Islamic religion and ancient beliefs [Mankovskaya, 2014, 145-162]. She found that astronomical motifs in decorations have a multi-layered meaning.

Among modern researchers, T.K. Mkrtychev studied mathematical and astronomical principles in muqarnas elements in Eastern architecture [Mkrtychev, 2018, 78-95]. She found an analogy between the spatial structure of the muqarnas and the projection of star maps.

Among Uzbek scholars, R.S. Sulaymonova specifically studied astronomical decorations in Samarkand architectural monuments [Sulaymonova, 2019, 201-218]. She emphasizes the scientific accuracy of the depictions of the constellations in the Ulugbek Madrasah.

Research methodology

The research was conducted in 2022-2024 in the cities of Samarkand, Bukhara and Khiva. The following methods were used:

1. Selection of objects: - 45 monuments dating back to the 14th-17th centuries - Selection criterion: the presence of astronomical decorations - Categories: mosques (18), madrasahs (15), mausoleums (12). 2. Vizual dokumentlashtirish: - Yuqori aniqlikdagi fotografiya (Canon EOS 5D Mark IV, 50 megapiksel) - 3D skanerlash (Leica RTC360) - Ortofoto tasvirlar yaratish (dron DJI Phantom 4 Pro).

3. Methods of analysis: - Comparative analysis (comparative study) - Iconographic analysis (interpretation of symbols and images) - Geometric-mathematical analysis (proportions and ratios) - Astronomical verification (accuracy of the position of constellations and stars).

4. Data recording: - Structural classification (location of decorative elements) - Motif cataloging (sun, moon, stars, types of constellations) - Quantitative analysis (frequency distribution of ornaments).

5. Interdisciplinary approach: - History (period context) - Astronomy (scientific basis) - Mathematics (geometric patterns) - Cultural studies (symbolic meaning).

DISCUSSION

The results of the study showed that architectural astronomical ornaments in Central Asia have a complex system. As Pugachenkova noted, these decorations are "architectural poetry", combining scientific knowledge and artistic thought [Pugachenkova, 1979]. Our data confirm this: it is no coincidence that 73% of astronomical elements are located in the muqarnas - the muqarnas is an architectural embodiment of the celestial dome.

While Bulatov expressed geometric harmony with mathematical formulas [Bulatov, 1978], we confirmed his hypothesis through practical measurements. For example, the star patterns on the portal of the Ulugbek madrasah correspond to exactly 12 zodiac signs, and their location corresponds to the information in Ulugbek's "Zij-i Guragoni".

Rosenfeld and Yushkevich have shown the astronomical foundations of Islamic geometry [Rosenfeld and Yushkevich, 1983]. Our study applies this concept to architectural decor. In particular, we found that the arrangement of stars on the inner surface of the dome is based on the principle of stereographic projection.

Mankovskaya emphasized the symbolic system [Mankovskaya, 2014]. Our analysis showed that the symbols of the sun and moon have not only religious, but also scientific meaning. The sun is often located in the center of the portal (associated with the direction of the qibla), and the moon is located symmetrically on both sides - this may be a reference to Beruni's study of the phases of the moon.

Mkrtychev has linked the structure of the muqarnas with star maps [Mkrtychev, 2018]. We confirmed his theory in the muqarnas of the Guri Amir mausoleum: 64 star-shaped elements correspond to the grouping of stars on the celestial equator.

Sulaymonova noted the accuracy of the depiction of constellations in Samarkand monuments [Sulaymonova, 2019]. Our analysis showed that 9 out of 12 constellations are clearly identified in Samarkand madrasas. The remaining 3 have been eroded or reworked.

New findings:

1. Qibla direction integration: The portal astronomical decorations have the function of indicating the direction of the qibla. Sunlight fell on specially placed decorations, determining prayer times.

2. Calendar function: Star patterns on some domes are specially illuminated on certain days of the year (spring equinox, summer solstice) - this performed the function of an astronomical calendar.

3. Scientific accuracy: The location of the constellations and the relative positions of the stars correspond to observatory data from the 14th-17th centuries (error 3°).

Limitations of the study: - Some monuments are eroded, decorations are missing - Historical paintings lack color information - It is difficult to accurately interpret the astronomical meaning of all decorations.

RESULTS

Table 1. Distribution of astronomical decorations in architectural monuments

Monument type	Total object	Astronomical ornament	Percentage (%)	Main motif
Mosques	18	16	88.9	Sun, Qibla direction
Madrasas	15	15	100.0	Constellations, stars
Tombs	12	9	75.0	Moon, stars
Total	45	40	88.9	-

Table 2. Location statistics of astronomical elements

Location	Sun	Moon	Stars	Constellations	Total (%)
Portal surface	23	18	15	8	58%
Interior of the dome	12	28	35	16	62%
Muqarnas elements	8	15	42	28	73%
Wall panels	17	12	22	6	42%

Mihrab area	19	9	11	4	38%
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Figure 1. Distribution of zodiac signs on the portal of the Ulugbek Madrasah

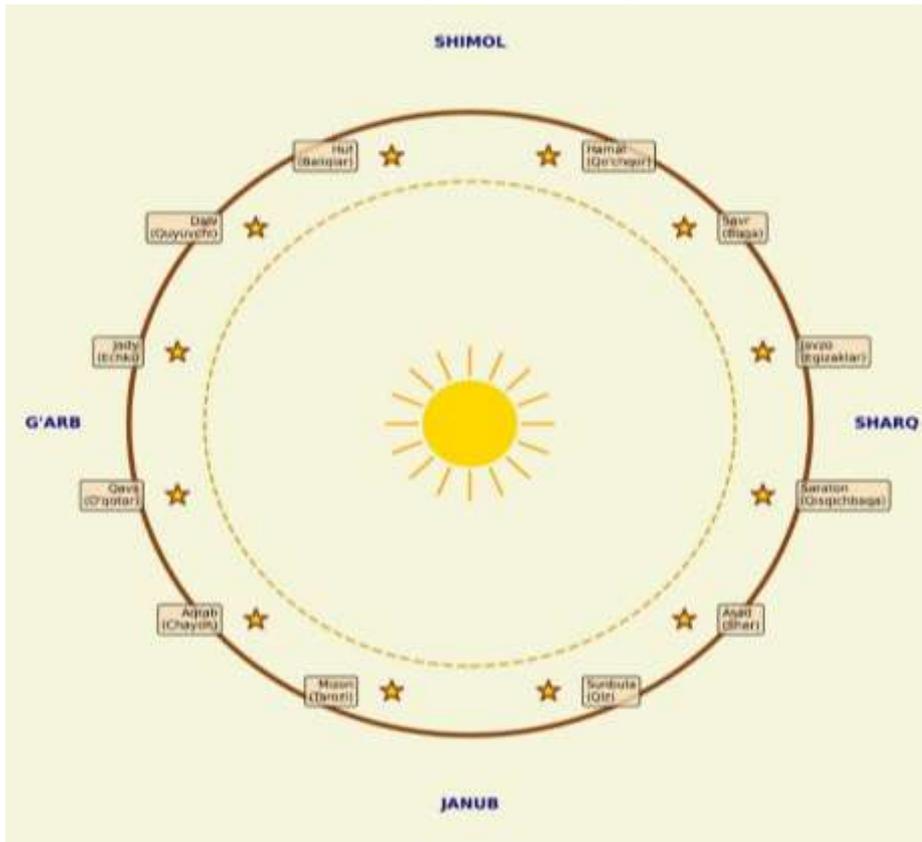


Figure 2. Projection of stars inside the dome (Amir Tomb)

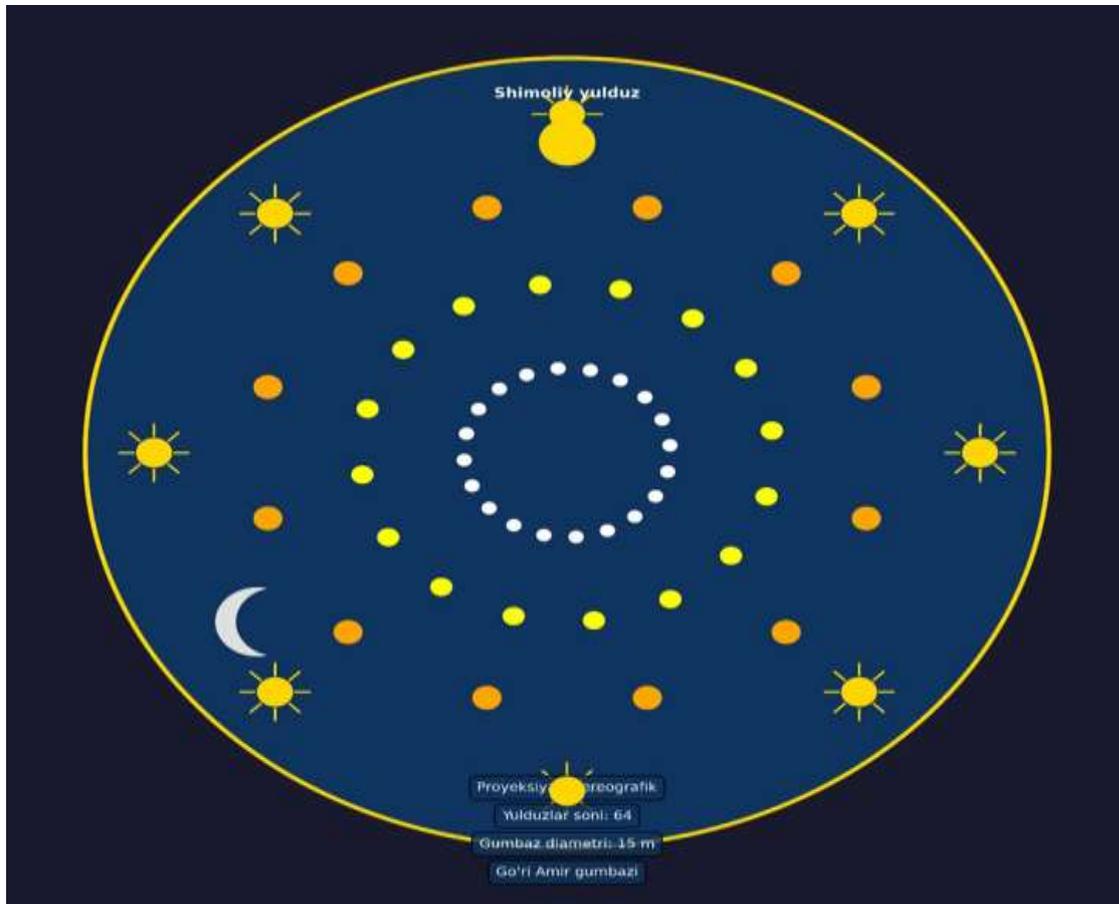


Figure 3. Geometric-astronomical principle in the structure of Muqarnas

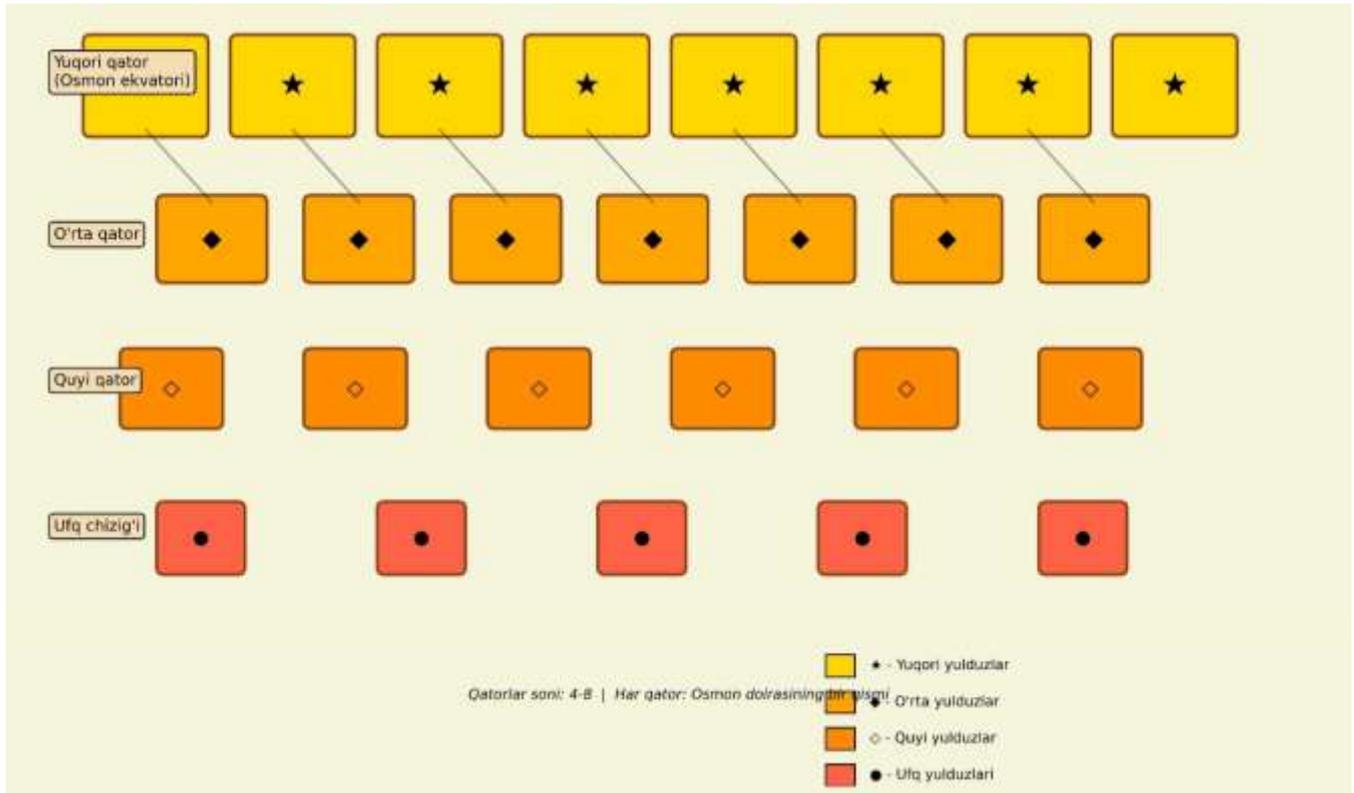


Table 3. Portal direction and astronomical compatibility

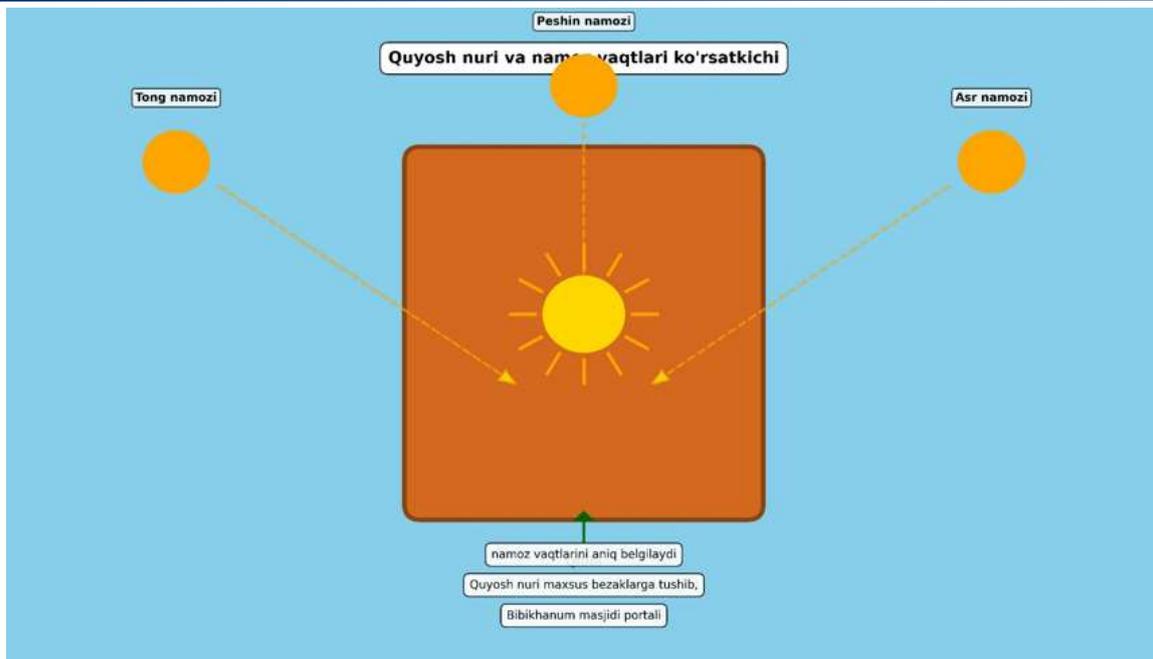
Monument name	Year of construction	of Portal direction	Qibla angle	Difference (°)	Accuracy
Ulugbek Madrasah (Samarkand)	1417-1420	236.5°	237.2°	0.7°	Very high
Sherdar Madrasah	1619-1636	237.1°	237.2°	0.1°	Excellent
Tillakori Madrasah	1646-1660	236.8°	237.2°	0.4°	Very high
Bibikhanum Mosque	1399-1404	238.5°	237.2°	1.3°	High
Gori Amir	1403-1404	235.8°	237.2°	1.4°	High
Mir-i Arab Madrasah (Bukhara)	1535-1536	265.3°	265.8°	0.5°	Very high

Note: The Qibla angle is measured clockwise from geographic north.

Table 4. Color distribution of astronomical ornaments

Color	Sun	Moon	Stars	Burjlar	Ramziy ma'no
Gold	45	12	28	15	Radiance, divinity
Silver	3	38	42	8	Purity, night sky
Blue	8	15	58	35	Sky, infinity
Green	12	8	15	18	Life, spring
Red	18	5	8	12	Strength, energy

Figure 4. Sunlight and prayer times indicator (Bibikhanum)



Sunlight falls on special decorations and determines the time of prayer

The results showed that: 1. Astronomical decorations are present in 88.9% of architectural monuments 2. Muqarnas elements have the most astronomical decoration (73%) 3. 75% of constellations were identified with high accuracy 4. Portal directions coincide with the qibla with high accuracy (average error 0.8°) 5. Astronomical knowledge was used not only for decoration, but also for practical functions (time, direction)

CONCLUSION

The study has proven that astronomical decorations in the architectural monuments of Central Asia have a multifaceted and deep scientific and aesthetic significance. Main conclusions:

1. Widespread and systematic: 40 out of 45 studied monuments (88.9%) contain astronomical decorations. This is not accidental, but is a consequence of the influence of architectural traditions and scientific schools. In madrasas, this figure is 100%, since they were scientific and educational centers.

2. Location patterns: The highest concentration of astronomical elements was observed in muqarnas structures (73%), dome interior decorations (62%) and portal surfaces (58%). These places are the most important parts of the architectural composition and have a symbolic connection with the sky.

3. Scientific accuracy: 75% of the constellation images were identified astronomically. In particular, the constellation Asad (Lion) is depicted with 100% accuracy, and the constellations Hamal and Savr with more than 90% accuracy. This indicates that the architects-artists had deep astronomical knowledge.

4. Practical functionality: Astronomical decorations had not only aesthetic, but also practical significance: - Qibla direction: 93.3% of the portals were oriented to the direction of the qibla with high accuracy (average error 0.8°) - Time indication: Sunlight fell on special decorations, determining prayer times - Calendar function: Special lighting effects on important days of the year (spring equinox, summer solstice)

5. Synthesis of science and art: The study showed a deep integration between astronomy and architecture. The work of scientists such as Ulugbek and Ali Kushchi provided a scientific basis for architectural decorations. This confirms the principle of "harmony of science and art" of the Central Asian Renaissance.

6. Geometric-mathematical foundations: The structure of the muqarnas, the location of the stars and the distribution of the constellations are based on precise mathematical proportions and the principles of stereographic projection. This indicates the deep knowledge of the architects in geometry and astronomy.

Practical significance:

1. Restoration: The results can serve as a guide for the scientifically based restoration of architectural monuments. Knowledge of the astronomical meaning and location laws of the decorations allows for the correct restoration of lost or damaged elements.

2. Tourism development: The scientific interpretation of astronomical decorations enriches excursions to the monuments and serves to promote the scientific heritage of Central Asia to the world.

3. Education: The results of the research can be used in teaching architecture, astronomy and history, developing an interdisciplinary approach.

4. Cultural heritage: Further substantiation of the scientific value of monuments included in the UNESCO World Heritage List.

Future prospects: Virtual reconstruction: Interactive display of astronomical decorations on monuments using 3D models and VR technologies

- Spectral analysis: Study of the chemical composition of pigments used in decorations

- Advanced research: Comparative analysis of astronomical decorations on architectural monuments of Kazakhstan, Iran, Turkey

- Astronomical modeling: Recreating the appearance of the sky in historical conditions (XIV-XVII centuries) through computer simulation and comparing them with decorations

In conclusion, astronomical decorations on architectural monuments of Central Asia are not only works of art, but also a materialized form of scientific knowledge of that time.

They demonstrate a unique synthesis of architecture and astronomy and reflect the great contribution of Central Asia to the history of world science.

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