PAYKAREH
Journal of Art Faculty, Shahid Chamran University of Ahvaz
Investigating and Analyzing Decorative Designs of «Non-Observational Astronomical Instruments» of the Safavid Period
Volume 12 Issue 34 Winter 2023 Pages 56-75

Original Research Article

Afsaneh Boyeri[1] Mitra Shateri[2]
Received: 13 March 2023 Revised: 29 November 2023 Accepted: 3 December 2023

DOI: 10.22055/PYK.2023.18677 **URL:** https://paykareh.scu.ac.ir/article_18677.html

How to cite this article: Boyeri, A, & Shateri, M. (2023). Investigating and Analyzing Decorative Designs of «Non-Observational Astronomical Instruments» of the Safavid Period. *Paykareh*, 12 (34), 56-75.

The Persian translation of this article is published in the same issue with the following title
بررسی و تحلیل آرایه‌های تزئینی «ابزارهای نجومی غیررصدی» دورهٔ صفوی

Investigating and Analyzing Decorative Designs of «Non-Observational Astronomical Instruments» of the Safavid Period

Abstract

Introduction: Astronomical instruments were made in different eras to observe the condition of stars, to identify the time, and to predict the future. They were produced for observatories in large dimensions and for scientists in small and portable sizes. Following the development of Islam and the need to know the religious times and determine the direction of Qibla, the production of non-observational instruments such as Qiblanama (Qibla compass), compass, and sundials flourished with the cooperation of astronomers and metalworking artists. Since most of the studies conducted in this field have been focused on observational instruments, especially astrolabes, the present study considered designs of «non-observational instruments» of the Safavid period. The purpose of this research is to examine the form, type, material, especially motifs, and decorative techniques of non-observational instruments of the Safavid period (due to the remarkable progress of astronomy and related instruments in this period).

Research Method: The current research is descriptive-analytical and comparative. The data collection was conducted through library sources and field surveys in museums inside or on the sites of museums outside Iran. In the current research, 35 instruments from the mentioned period have been examined.

Results: The data of the research indicates that the non-observational astronomical instruments are primarily in four types of celestial spheres, Qiblanama (Qibla compass), compass, and sundials, and they are mainly made of brass. In the Safavid period, along with the shapes of constellations and inscriptions, plant motifs, prayers, and Persian poems in Naskh or Nastaliq were used for decoration. Also, the decorative techniques used in the instruments of this period, in addition to carving, were stone loading, silver inlay, gold inlay, and latticework.

Conclusion: Most of the non-observational instruments made in the Safavid period had a personal function and were mainly used to find the way and recognize the direction of the Qibla and to identify the religious times, and were also used as gifts. It seems that the reason for the construction and production of these objects in the Safavid period was the significant expansion of commercial and political relations, the increase in travel, and the prosperity of communication with Europeans, and these relations influenced the presence of Roman script on some of these items.

Keywords

Non-observational Instruments, Decorative Designs, Celestial Spheres, Qiblanama (Qibla compass), Compass, Sundials

1. M A. Archaeology, Faculty of Literature and Humanities, Shahrekord University, Shahrekord, Iran.
2. Corresponding author, Associate Professor of Archaeology, Faculty of Literature and Humanities, Shahrekord University, Shahrekord, Iran.
Email: Shateri.mitra@sku.ac.ir

Introduction

Astronomical instruments in the Islamic era in line with the various necessities and needs in the lives of Muslims, such as knowing the time of sunrise and sunset for performing prayers, as well as geographical issues, especially navigation, the phenomenon of fortunetelling, and identification of Sa'd (lucky) and Nahs (unlucky) days, nights, and hours, became one of the most important scientific phenomena. The great belief of the Mongols in celestial bodies and their relationship with human destiny caused them to pay special attention to astronomy and its development. The Maragheh observatory was established with the help of «Khwaja Nasir-al-Din Tusi», in which critical astronomical instruments such as Armillary Sphere (Zat al-Halaq), Halqat al-'iniqlāb, and Halqat al-'itidāl were built, which significantly contributed to the progress of astronomy. Among the Timurid sultans, «Ulugh Beg» had a great interest in astronomy and was considered among the scientists and astronomers of his era, and the construction of the Samarkand observatory had a significant impact on the advancement of this science. In the Safavid period, although the kings had great faith in astrology, superstition, and Sa'd (lucky) and Nahs (unlucky) affairs, and they consulted astrologers in many matters related to the country, the development of this science became slower. According to travel writers, superstition and astrology are very popular among the public. Accordingly, the instruments of astrology, such as the astrolabe, continued to be made, and the more scientific tools and decorative motifs used on them also became more diverse and widespread. Most of the instruments of this period are astrolabes and compasses, many of which are among the artistic masterpieces of Iran and the world. In a general classification, astronomical instruments are divided into two groups of observational astronomical instruments (such as astrolabe[1], Rob'[2], Zat al-sho'bateyn[3], Zat al-Samt va al-Ertefa'[4], Zat al-Halaq[5], and Sods[6]) and non-observational astronomical instruments (including of celestial spheres, Qiblanama (Qibla compass), compass, and sundials). Most of the studies conducted are focused on observational instruments, especially astrolabes, and no independent and comprehensive research has been conducted in the field of non-observational instruments in Iran. Therefore, due to the expansion of the construction and production of non-observational instruments in the Safavid period, the current research is focused on this group of scientific instruments. With the aim of investigating the form, type, material, and especially the arrays and decorative techniques of non-observational instruments in this period, this research seeks to answer these questions: «What types of non-observational astronomy instruments were included in the Safavid period, and from the morphological point of view, what patterns and decorative techniques were used in their construction?»

Research Method

The statistical population of the present study includes thirty-five non-observational instruments from the Safavid period. This research is descriptive-analytical and comparative in terms of method, and the data collection was conducted through library studies and field surveys in museums inside or outside the country using purposeful sampling. These instruments, which include eight celestial spheres, twenty-one Qiblanama (Qibla compass), and compasses, as well as seven sundials, were examined in separate

tables in terms of materials, motifs, and decorative techniques. The prevalent motifs of this period are common and have differences in scripts.

Research Background

There have been many studies on astronomy and its instruments in the Islamic era, which have mainly focused on observational instruments. Among the novel studies, «Varjavand» (2005) authored the book entitled «Explorations of the Maragheh Observatory and a Look at the History of Astronomy in Persia» and mentioned the astronomical instruments of this observatory. In the book entitled «Instruments of Maragheh Observatory», «Ghazni» (1977) introduced this observatory, its founder, and its instruments in general. In the article entitled «Compass and Qiblanama (Qibla compass)», «Hasanzadeh Amoli» (1993) discussed finding directions through the compass and distinguishing the compass from the Qiblanama (Qibla compass). The article entitled «Amazing Developments: The Celestial Sphere and Zat al-Halaq» by «Mozaffari» (2009) introduced several celestial sphere from different eras. In the article entitled «Secrets of Isfahan's Qibla compasses», «Hogendijk» (2012) introduced three Qibla compasses made in Isfahan, which were presented at Sotheby's auction. Also, in the article entitled «The List of Persian Sundials», «Bagheri» (2014) discussed the background of sundials with a focus on sundials in Iran. In the article entitled «The Abd al-Aima's Astrolabe Forgeries», «King and Saliba» (1972) argued about «Abd al-Aima» and the astrolabes made by him. In the article entitled «Introduction of Persian Astronomy to India» «Ohashi» (2008) discussed the introduction of Persian astronomy in India and its influence on the instruments made in India. As can be seen, the mentioned studies have been conducted on general references regarding astronomical instruments and focusing on observational instruments, especially astrolabes, and independent and comprehensive research has not been conducted on non-observational instruments. Accordingly, the present research is an effort to identify non-observational instruments and their arrays in the Safavid period.

Astronomy Instruments

In the distant past, human beings realized that in order to satisfy their curiosity and needs, they should acquire the knowledge that will help them live a better life in nature. Among these sciences was astronomy. Over time, scientists realized that the course of celestial bodies relies on order and law, that identifying them and discovering their secrets can make it possible for humankind to know about this rotating sky and to understand the quality of the law that governs this course and movements, they tried to invent its tools and devices (Nabaei, 1986). It should be acknowledged that, after the emergence of Islam in Iran, astronomy was respected by different classes in terms of performing religious duties, and the study of this science, even if its prerequisites, was very obligatory for Muslims due to the lack of clocks and compasses. Therefore, astronomers and astrolabe makers tried to invent and build devices that would satisfy people's needs in this sense (Ehsani, 2011, 206). Persian Muslim astronomers used various instruments in their astronomical observations. Current knowledge about these instruments has been obtained in two ways. First, the surviving astronomical instruments, and second, the treatises that exist in the form of manuscripts in different libraries and contain information about these instruments and the

method applied to use them. These instruments can be classified into two groups: Observational and non-observational astronomical instruments. Although all of these tools were used in astronomical observations, non-observational instruments were primarily used in solving the problems of spherical astronomy and related mathematical calculations, the timing of the rising and setting of the moon, the sun, and the stars, and the passage of these objects through the observer's meridian. Some astronomical instruments, such as astrolabes and some types of Rob' (quarter), were used in both calculations and observations (Giahi Yazdi, 2009, 47-49). Regarding astronomical instruments, it is said that Muslims had a particular interest in making such instruments, and in mosques all over the Islamic world, indicators were almost always made to determine the time (Aram, 1987, 126). In this section, the types of non-observational instruments used in the Safavid period will be examined.

Non-Observational Instruments

Non-observational instruments include tools that were not used in astronomical observations and were more involved in solving astronomical problems and calculations related to astronomy. This category of instruments had different types, including celestial spheres, Qiblanama (Qibla compass), compass, and sundials, which were often made in smaller dimensions and sizes compared to observational instruments.

1. Celestial Sphere: One of the astronomical instruments is a celestial sphere that is usually placed in the middle of a ring that is like a meridian in a place called Korsi (Biruni, 2009, 127-8). There are two types of celestial spheres: one for teaching circles and the other for astronomical practices in which the fixed stars are depicted in the appropriate place (Roohfar, 1996). Many of these instruments have constellations, some only have stars, some have no stars, and a number of them include astronomical motifs. In all Islamic celestial spheres, six large circles are drawn perpendicular to the orbit of the Sun (Khalili, 2008, 130) (Fig 1).

Fig 1. Celestial sphere, Ilkhanid period. Source: History of Science Museum, Oxford History Museum.

2. Qibla Compass (Qiblanama): By determining Mecca as the Qibla[7] of the Muslims, the altars of the mosques were built in a specific direction. However, with the expansion of Islamic lands and the construction of more mosques, the Muslims still did not have the same method for determining the direction of the Qibla. With the advancement of science and the emergence of scientists, instruments were produced that made it possible for Muslims to determine the Qibla everywhere. Based on its function, these instruments were called the Qibla compass (Qiblanama) (Fig 2).

Fig 2. Qibla Compass (Qiblanama), Safavid period. Source: Archive of Astan Quds Razavi Museum.

3. Compass: In a manuscript of «Mohammed bin Al-Hassan Tostari», which is about the science of astronomy, the following is mentioned in the definition of the compass: «Among the artifact instruments used to determine the direction of the Qibla, is the compass» (Hasanzadeh Amoli, 1993). Most scientists believe that Persians made the compass. Unlike the Chinese compass, which had 24 directions, the Persian compass had 32 directions. The number 32, in addition to showing the greater accuracy of the Persian compass, indicates the familiarity of Persians with numbers in base 2 (binary scale) and their advanced mathematical knowledge. In the early Islamic era, the Iranians added a Qiblanama to the compass so that the correct direction of the Qibla could be found in any situation (Sepehri, 2008).

4. Sundial: A sundial is an instrument that has a vertical blade or rod, and this blade or rod rests on the center of a horizontal circular plate through the shadow that is produced by the sunlight from this blade or rod falls on the screen, it determines the time (Dehkhoda, 1998, 13302). This small instrument, which was made of brass and smaller than a pocket watch, was used in the middle Islamic ages, when there were no clocks or Qibla compasses among Iranians, in traveling across the sea, determining the hours of the day, navigation, and finding the direction of Qibla. As the need for more accurate measurements increased and mathematics and astronomy developed, the simple indicator, or Mezwalah, turned into the sundial. Muslims played a significant role in the development of the knowledge of making sundials, but the applications of complex clocks in Iran have been very limited compared to the Western regions of the Islamic world (Mashkourian, 2016) (Fig 3).

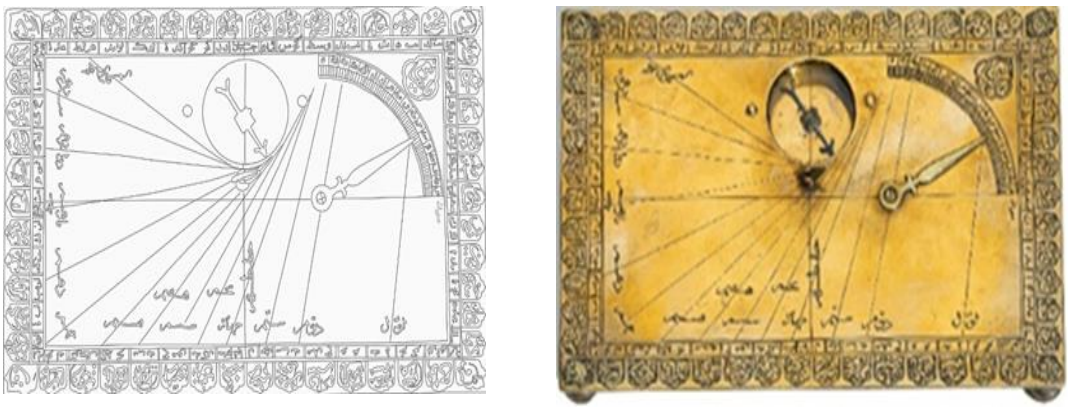


Fig 3. Combination of sundial and Qiblanama (Qibla compass), Safavid period. Source: Sotheby's website.

The History of Astronomy and the Construction of Non-Observational Instruments before the Safavid Period

The Seljuk period was one of the most brilliant periods in the construction of metal astronomical instruments, such as various flat and spherical astrolabes. Sundials were also produced with decorations and decorative techniques such as stone loading. In the meantime, astronomical concepts with constellations, zodiac, and astrological signs were the most widespread themes of decorations on the surface of these works. With the emergence of the Mongol Illkhanids, the process of astronomy was influenced by their beliefs in magic and superstition because the most essential tool of Mongol sorcerers was the constellation of astronomy. Therefore, astronomy had a special status and dignity among them (Boyle, 2001, 372). Astronomy progressed during the Timurid period, continuing the Ilkhanid period. During this era, among the scientists who were always present in Timur's camp, there were astronomers whom Amir Timur would ask about Sa'd (lucky) and Nahs (unlucky) hours before implementing any decision (Shami, 1984, 119). During this period, progress was made in astronomy science, which included both theoretical issues and practical and experimental methods (Kennedy, 2000, 282). The observatory that Ulugh Beg built in Samarkand was one of the wonders of the world. He ordered the construction of new instruments and wrote his famous calendar table and Zij (Bouvat, 2005, 161-162). Despite the expansion of astronomy in these centuries, a small number of astronomical objects and instruments have remained from these periods. Perhaps the reason for this can be considered the low production of metal tools or the melting of these objects in later periods because due to the invasion of the Mongols into Iran, we could witness the decline of the metalworking industry and the decrease in the production of metal containers and the allocation of as much metal as possible to the manufacture of war tools and instruments (Bayani, 2000, 161).

Astronomy in the Safavid Period

Due to the special attention of the kings of the Safavid period, especially Shah Abbas I, arts and crafts grew increasingly during this period (Kolahkaj & Esfandiari Qorabi, 2021, 61). In this period, the science of astronomy developed considerably due to the great attention paid to Sa'd (lucky) and Nahs (unlucky) days. During this era, astronomers had a high position in the court, and being an astronomer was one of the most critical court positions in the Safavid government. The Shah did not do anything without his approval and instructions. Extreme attention to astrological regulations and their prominent role in national and military matters caused the spread of superstitions in this period (Esfandiari Mohani, 2018).

Non-Observational Instruments of Astronomy in the Safavid Period

At the end of the Timurid period, astronomy and the production of instruments related to it stagnated; however, with the beginning of the Safavid reign, this industry started its performance again. One of the distinctive features of the Safavid period in astronomy was the extensive interest of tool makers in constructing astronomical instruments, especially the astrolabe, Qiblanama, sundial, and Rob' al-Mujib (Giahi Yazdi, 2009, 99). The non-observational instruments identified in this period show an increasing variety and quantity compared to previous periods. These tools were made by artists in different cities.

Undoubtedly, the most famous astronomical instrument maker of the Islamic period, whose artifact has survived, should be considered «Abd al-Hossein Abd al-Aima», a renowned craftsman of the Safavid era. Most of the non-observational tools made in this period mainly had personal functions, and some of their types, especially the Qiblanama, compass, and sundials, were used by a group of people who were not necessarily astronomers and astronomy scientists; they have used the mentioned instruments to find the direction and navigation, recognize the direction of the Qibla, and identify the religious times. In this section, 35 non-observational instruments identified from the Safavid period, including eight constellations, 21 Qiblanama (Qibla compass), and seven sundials, will be examined.

Celestial Spheres

From the Safavid period, eight constellations have been identified, which were made in the same sizes as in the previous periods. One of the most prominent of these spheres is kept in the Astan Quds Razavi Museum. The base of this sphere consists of a horizontal metal ring that is placed on a 13-cm high vertical stand. The horizon ring is fully calibrated, and in addition to the four main directions, one of the Abjad numerals is written every 5 degrees on the circle of the sphere. On the sphere is the phrase « عمل ضیاء الدین محمد بن قائم محمد بن ملاعیسی ابن ملا الهداد اسطرلابی همایونی لاهوری سنه ۱۰۵۸هجری». The spherical part, with a height of 22 cm and a diameter of 15 cm, is located on a stool (Habibi Qaeini, 2009 a) (Table 1, Row 2). In this section, general information and characteristics of the material, motifs, and decorative techniques of spheres in this period will be presented in Table 1 (Fig 4).

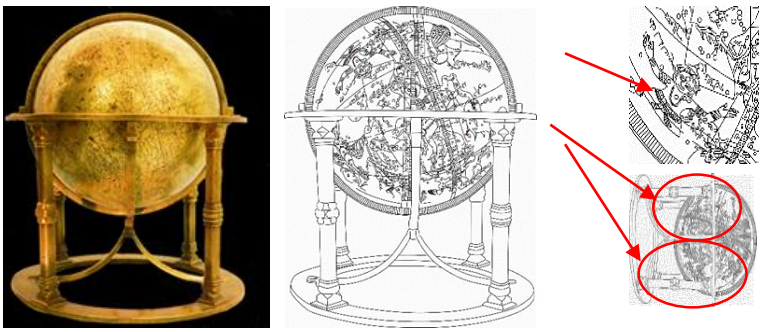


Fig 4. Celestial sphere and samples of human, animal, and inscription motifs. Source: Astan Quds Razavi museum archive.

Materials, Motifs, and Decorative Techniques: All the spheres obtained from this period are made of brass. Unlike astrolabes, which were sometimes made of other metals, it seems that brass was the only metal used in making this instrument. The main decorations applied to the Safavid period celestial spheres are inscriptions, constellations, and astrological signs. The inscriptions were composed of the names of the stars, Abjad numerals, the name of the creator and the date, the ecliptic, geographical coordinates, and the tropics of Meridian and Capricorn. The images of the constellations and astrological signs are also illustrated by drawing humans, animals, or a combination of other common motifs used on the celestial spheres. Many of these decorations have been executed with decorative methods of

engraving and sometimes silver inlaying on the brass surface of spheres, which are mostly placed on stools (Tables 1 & 2).

Table 1. Features of celestial spheres in terms of materials, motifs, and decorative techniques. Source: Authors.

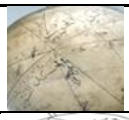
Image	Sample of Decoration	Description
		Material: Brass Type and theme of the motif: Human and animal (constellations and astrological signs), inscriptions (names of the constellations, the name of the creator, Muhammad Zaman, the time, place, and construction date: 1050 A.H.). Decorative techniques: Silver inlaying and engraving Location: Victoria and Albert Museum, London.
	 	Material: Brass Type and theme of the motif: Human, animal (constellations), inscriptions (names of constellations: Zia al-Din Muhammad bin Qaim Muhammad bin Mulaisi Ibn Mullah - Alhadad Astrolabi - Homayuni Lahori, construction date: 1085 A.H.) Decorative techniques: Engraving Location: Astan Quds Razavi Museum
		Material: Brass Type and theme of the motif: Human, animal (constellations) and inscriptions (names of constellations, construction date: 11th century A.H.) Decorative techniques: Silver inlaying Location: Roseberry Auctions, London
		Material: Brass Type and theme of the motif: Inscription (Abjad numerals, division of circles and poles of the sphere, construction date: 11th century A.H.) Decorative techniques: Engraving Location: Roseberry Auctions, London
		Material: Brass Type and theme of the motif: Inscription (names of astrological signs, construction date in 1024 A.H.) Decorative techniques: Engraving Location: Roseberry Auctions, London
		Material: Brass Type and theme of the motif: Inscription (the names of astrological signs, date of construction in the late 11th century A.H.) Decorative techniques: Engraving Location: Bonhams Auctions
	 	Material: Brass Type and theme of the motif: Inscription (constellations and astrological signs, date of construction: 1111 A.H.) Decorative techniques: Engraving Location: Oxford Science Museum

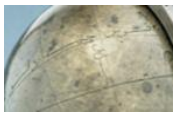
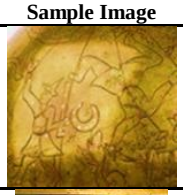
Image	Sample of Decoration	Description
		Material: Brass Type and theme of the motif: Inscription (names of astrological signs and total declination (Mil), date of construction: 11th century A.H.) Decorative techniques: Engraving Location: Oxford Science Museum

Table 2. Features of celestial spheres of the Safavid period in terms of the theme of motif. Source: Authors.

Sample Image	Description
	Type of motif: Human and animal, inscription The theme of motif: Constellations and astrological signs, the names of the constellations, the name of the maker, Muhammad Zaman, the place (Mashhad), and construction date, 1050 A.H.) Location: https://V&A Museum.com access date (15/11/2019)
 	Type of motif: Human and animal, inscription The theme of motif: Constellations and names of the constellations. Zia al-Din Muhammad bin Qaim - Muhammad bin Malaisi Ibn Molla Al Hadad Astralabi - Homayuni Lahori, construction date is 1085 A.H. Location: Astan Quds Razavi Museum
 	Type of motif: Human and animal, inscription The theme of motif: Constellations and names of the constellations, construction date is the 11th century A.H. Location: 2/4/2020 (access data). https://Roseberys.co.uk
-	Type of motif: Inscription The theme of motif: Abjad numerals, division of circles and poles of the spheres, construction date is 11th century A.H. Location: http://Rosebrys.co.uk.access data(2/4/2020)
	Type of motif: Inscription The theme of motif: The names of astrological signs, construction date is 1024 A.H. Location: https://Rosebrys.co.uk access data (2/4/2020)
	Type of motif: Inscription The theme of motif: The names of astrological signs, the construction date is late 11th century A.H. Location: http://Bonhams.com access data (27/10/2020)

Sample Image	Description
	Type of motif: Inscription The theme of motif: Constellations and astrological signs, the construction date is 1111 A.H. Location: http://hsm.ox.uk access data (6/12/2019)
	Type of motif: Inscription The theme of motif: The names of astrological signs and total declination (Mil), the construction date is late 11th century A.H. Location: http://hsm.ox.uk access data(6/12/2019).

Qiblanama (Qibla Compass) and Compasses of the Safavid Period

Another group of non-observational instruments of the Safavid period are Qiblanamas, most of which were made in Isfahan based on existing inscriptions and are considered scientific and artistic masterpieces. These metal Qibla compasses also had a sundial (Bagheri, 2014). This means that the creators could make them both separately and in the form of an instrument, and their owners could use them both (to determine the direction of the Qibla and the hours of the day). This instrument was made in specific forms, and 21 of them were identified in the investigations. One of these works is a Qibla compass presented at Sotheby's auction center in London, and it shows the signature of Muhammad Khalil Ibn Hasan Ali along with the date 1080 A.H. This Qibla compass consists of two circles with a hinged door. Inscriptions are engraved on it, and bands are embossed around it. Its inside includes a glass frame and a compass that points towards the Ka'ba. This Qibla compass, which was made in Isfahan, has a sun dial on which the names of the cities of Mecca Mukarama, Medina Tayyaba, Mashhad, Najaf Ashraf, Kadhimayn, and the South are engraved. It should be noted that 12 astrolabes have been identified with the name of the creator of this Qibla compass (Mohammed Khalil Ibn Hasan Ali), which shows the specialization of this career in the Safavid period (Hogendijk, 2012) (Table 3, Row 1). In the same auction center (Sotheby's) in 1989, another Persian Qibla compass was sold, probably in 1112 A.H. It was made in Isfahan. This Qibla compass was designed based on the cartography network[9] so that the Qibla can be read directly from the map. Mecca is located in the middle of the network, and it is enough to place the metal arm of the Qibla compass over the cities marked on the map (from Spain to China) and read the direction of the Qibla from the calibrated margin of the instrument. This instrument has a dial that rotates around its axis on a flat plate on which a map of the sphere is engraved. There is also a compass on the screen (King, 1996). This Qibla compass is made based on complex mathematical calculations and is considered one of the masterpieces of Persian instrument making in the Islamic period (Table 3, Row 10). Three distiches of Persian poetry have been written on this Qibla compass as a guide for using the instrument: در این صحرا که در معنی زمین و آسمانستی/ سوی قطب جنوبی رو کند چون مرغ نیلی پر/اگر ستاره را بر عرض و طول شهر بگذاری/ شوی از قبله و بُعد بلد از قبله مستحضر/ مطابق گر کنی عرض بلد با صفحهٔ ساعت/ سوی تشخیص ساعت ظل شاخص گرددت رهبر. Another sample is a Qibla compass accompanied by a compass, which is 7.5 cm in diameter and decorated with engraved motifs and scripts with an engraved silver frame. The cover of this work from the outside includes ten concentric circles, in which the names of the cities are engraved along with their inclination and direction. The main page consists of three circles, and besides the pointer, it also has a sun dial, and the names of some cities are written on

the third circle. The names of holy Islamic towns are also engraved on the bottom of the Qibla compass from the inside, and a moving compass is also installed on the inner bottom (Table 3, Row 2) (Habibi Qaeini, 2009 b). In the Safavid reign, the production and use of the Qiblanama and compass increased significantly compared to the previous periods. Perhaps the reason for this can be seen in the prosperity of trade and extensive international relations of the Safavid government with neighboring and European countries, as well as the increase in business trips and the presence of tourists, businessmen, and diplomats.

Materials, Motifs, and Decorative Techniques: The general shape of all Qibla compasses and compasses is circular and they are mainly made of brass and sometimes bronze or silver. In some cases, hinges or doors of brass compasses are made of silver and then attached to the brass part. Most of the decorative motifs used in these works are inscription motifs with different scripts, especially Thulth, Naskh, and, for the first time, Nastaliq on the instruments of this period. In addition to the names of the tool-makers, the inscriptions show the names of the major cities of the Islamic world and the main geographical directions or the names of the constellations and the astrological signs. In some cases, plant, human, and animal motifs have also been used in addition to inscription motifs. These motifs have been executed in various decorative ways such as engraving (in Persian poems, the name of the tool-maker and the date of construction, and the names of cities), stone loading with precious and semi-precious stones, and latticework (in the making of lids) on Safavid period compasses. In this section, the general information obtained from the 21 Qiblanamas (Qibla compass) and compasses of the Safavid period is classified and presented in Table 3.

Table 3. Features of Qibla compass and compasses of the Safavid period based on material, motif, and decorative techniques. Source: Authors.

Image	Sample Decoration	Description
	 	Material: Brass Type of motif: An inscription in Thuluth script and a copy of Arabesque plant motifs around the inscriptions Type and theme of the motif: Abjad numerals, cities, inclination of cities, directions, and the name of the tool-maker, Muhammad Khalil bin Hassan, construction date in 1080 A.H. Decorative techniques: Engraving and latticework Location: Sotheby's Auctions
	 	Material: Brass with a silver lid Type of motif: An inscription in Thuluth script Type and theme of the motif: Abjad numerals, main directions, names of cities, numbers 1 to 5, construction date in 11th century A.H. Decorative techniques: Engraving and latticework Location: Astan Quds Razavi Museum
		Material: Brass Type of motif: Inscriptions and Arabesque plant motifs Type and theme of the motif: Names of cities, inclination of cities, directions and Abjad numerals, construction date in the 11th century A.H. Decorative techniques: Engraving Location: Astan Quds Razavi Museum

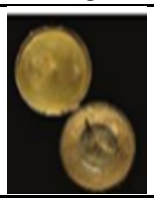
Image	Sample Decoration	Description
	-	Material: Brass Type of motif: Inscription Type and theme of the motif: Names of cities, inclination of cities, directions and Abjad numerals, construction date in the late 11th century A.H. Decorative techniques: Engraving and latticework Location: http://Bonhams.com. Access date (27/10/2020)
	 	Material: Brass Type of motif: Inscription in Thuluth script. Arabesque, Khataei, and plant motifs on the margins Type and theme of the motif: Names of cities, Persian poetry (ببین بعد بلد را از جنوب و برشمار آنگه ...), Abjad numerals and main directions, construction date in 11th century A.H. Decorative techniques: Lattice work and engraving Location: http://sothb'ys.com. Access date (21/3/2020)
		Material: Brass Type of motif: Inscription in Thuluth script. Arabesque plant motifs on the margins Type and theme of the motif: Names of cities, Persian poetry (ببین بعد بلد را از جنوب و برشمار آنگه ...), Abjad numerals, name of cities, construction date in 11th century A.H. Decorative techniques: Engraving Location: http://Bonhams.com. Access date (27/10/2020)
	  	Material: Brass Type of motif: Inscription in Thuluth script. Geometric and plant motifs Type and theme of the motif: Abjad numerals, name of cities, construction date in 11th century A.H. Decorative techniques: Engraving and latticework Location: http://Bonhams.com. Access date (27/10/2020)
	 	Material: Brass Type of motif: Inscription in Thuluth and Nastaliq script. Arabesque, Khataei, and plant motifs on margins Type and theme of the motif: Abjad numerals. The tool-maker's name, Muhammad bin Zakaria. The names of the cities, their inclination, and direction. Construction date, 11th century A.H. Decorative techniques: Engraving Location: http://Christi'es.com. Access date (3/11/2020)
	 	Material: Brass Type of motif: Inscription in Thuluth Type and theme of the motif: The names of the cities. Construction date, 11th century A.H. Decorative techniques: Engraving Location: http://Bonhams.com. Access date (27/10/2020)
		Material: Brass Type of motif: Inscription in Nastaliq Type and theme of the motif: Persian poetry (در این صحرا که در معنی زمین و آسمانستی سوی قطب). Decorative techniques: Engraving Location: http://Christi'es.com. Access date (3/11/2020)

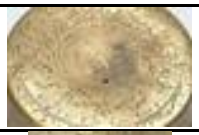
Image	Sample Decoration	Description
		Material: Brass Type of motif: Inscription Type and theme of the motif: Abjad numerals, names of cities, main directions, Nad Ali's prayer, construction date, 11th century A.H. The name of tool-maker, Abd al-Aima Decorative techniques: Latticework, engraving Location: http://Mia.org.qa access date (15/11/2019)
		Material: Brass Type of motif: Inscription in Thuluth script Type and theme of the motif: Abjad numerals, the name of tool-maker, Abd al-Aima in the center, the names of the cities, and their inclination and directions. Decorative techniques: Engraving and latticework Location: http://malekmuseum.org. Access date (2/12/2020)
		Material: Brass Type of motif: Inscription in Thuluth script Type and theme of the motif: Names of cities, main directions Decorative techniques: Engraving Location: http://Chsi.harvard.edu. Access date (2/12/2020)
	 	Material: Brass Type of motif: Inscription in Naskh script Type and theme of the motif: Names of constellations, astrological signs Decorative techniques: Engraving and latticework Location: http://Antique.com. Access date (13/12/2020)
		Material: Brass Type of motif: Inscription in Thuluth script Type and theme of the motif: Name of cities, Abjad numerals, shadows (Zal) and declinations (Mil) Decorative techniques: Engraving Location: http://hsm.ox.uk. Access date (6/12/2020)
	 	Material: Bronze Type of motif: Inscription in Thuluth script Type and theme of the motif: Abjad numerals, name of astrological signs, the camel motif in the center Decorative techniques: Engraving and latticework Location: http://Antique.com. Access date (13/12/2020)
	 	Material: Bronze Type of motif: Inscription, Arabesque motifs, human (rider) - animal motifs Type and theme of the motif: Abjad numerals, cities, name of astrological signs, construction date, the 11th century A.H. Decorative techniques: Engraving and latticework Location: Ardabil Archaeological Museum
		Material: Bronze Type of motif: Inscription, Arabesque motifs, human and animal motifs Type and theme of the motif: Name of astrological signs, construction date, the 11th century A.H. Decorative techniques: Engraving Location: Ardabil Archaeological Museum

Image	Sample Decoration	Description
		Material: Silver Type of motif: Inscription in Naskh script, Arabesque and plant motifs Type and theme of the motif: Nad Ali's prayer, construction date: 11th and 12th century A.H. Decorative technique: Engraving, Stone loading, and Latticework Location: https://V&A Museum.com. Access date (15/11/2019)
		Material: Brass Type of motif: Inscription in Naskh script Type and theme of the motif: Name of cities, Abjad numerals, Persian poem (شعر ببین بعد بلد را از جنوب...) Decorative techniques: Engraving and latticework Location: http://Bonhams.com. Access date (27/10/2020)
		Material: Brass Type of motif: Inscription in Naskh and Thuluth script Type and theme of the motif: Name of cities, Abjad numerals, Persian poem (شعر ببین بعد بلد را از جنوب...), Cities' inclinations Decorative techniques: Engraving and latticework Location: http://Christi'es.com access data(3/11/2020)

Sundials

According to the available evidence, sundials (Mezwalah) have existed and have been used for a long time. In the Islamic era, especially in the Safavid era, this instrument was made and used to know the exact time, especially the religious times of prayer. The installation of large rod or stone sundials in large and essential mosques in major cities such as Isfahan is proof of this claim, and the sundials of Atiq Jameh Mosque, Qutbieh Mosque, Abbasi Jameh Mosque (Saeidnia, 2008) and Hakim Mosque are among the remaining samples from this period. Based on the investigations and the work that was obtained, these clocks were sometimes placed on the Qiblanama (Qibla compass). According to the documents left from the Safavid period, in addition to sundials, all kinds of clocks were among the most critical items offered to the Safavid court or from the Safavid court to other countries, and trading all sorts of European clocks was welcomed (Chardin, 1959, 222; Tavernier, 2010, 154-155). The use of European motifs and Roman numerals on these clocks and the prosperity in their market caused even Persian artisans to use European motifs and Latin numerals in making sundials. From the Safavid period, 7 sundials were identified, and their characteristics will be examined in this section.

Materials, Motifs, and Decorative Techniques: Sundials were hand-made in two circular and rectangular shapes, made of brass or stone. This instrument worked by reflecting the sun's shadow on a small circular plate inside a brass can with a diameter of 5 cm. These small plates were divided and calibrated with the names of the cities and the four directions in the Naskh and Nastaliq scripts. This type of sundial was primarily made in Yazd and Isfahan (Ehsani, 1989, 206). Like other instruments made in this period, the inscription motifs include the name of the tool-maker and the date of construction, the names of Islamic cities, the numbers and digits of the hour from 1 to 14[10], the inclinations of cities with Abjad numerals on their margins, as well as the main geographical directions. Sometimes, Roman numerals have been used on the main face of sundials, which can be seen as the result of extensive communication with European governments in this era. Four samples of the obtained sundials include the name of Abd al-Aima, an artist and craftsman. A sample of a

Qibla compass he made is also introduced in the current research. He was one of the most prominent artists and craftsmen, famous and proficient in making various astronomical instruments during the Safavid period. In his fame and skill, it is enough to say that today, more than 50 astrolabes are identified with his name (Afrough, 2014). The use of Arabesque plant motifs and the Sun motifs are the most widely used motifs after inscription ones. Using the Sun motif is directly related to the use of this instrument as a sundial. These motifs are all engraved on the instruments by carving and sometimes lattice working. In Table 4, the features and information obtained from sundials attributed to the Safavid period are presented.

Table 4. Features of Safavid period sundials based on form, material, motifs, and decorative techniques. Source: Authors.

Image	Sample Decoration	Description
	-	Form: Circular Material: Brass Type and theme of the motif: Inscription (Construction date, 950-1000 A.H.) Decorative techniques: Latticework, engraving Location: Charles Chad Knight Collection, Paris Ghazni, 1977, 287.
	 	Form: Circular Material: Stone Type and theme of the motif: Inscription (Roman numerals), the Sun motif in the center Decorative techniques: Engraving Location: Astan Quds Razavi Museum Habibi Qaeini, 2009 b.
		Form: Circular Material: Brass Type and theme of the motif: Inscription (Roman numerals), the name of tool-maker, Mohammad Hossein, construction date, 1071 A.H. Decorative techniques: Engraving, Latticework Location: Christie's auction, https://Christie's.com access date (3/11/2020)
	 	Material: Rectangular Material: Brass Type and theme of the motif: Inscription (name of tool-maker, Abd al-Aima, Abjad numerals, names of cities), construction date, 12th century A.H. Decorative techniques: Engraving Location: Unknown Khalili, 2008.
		Material: Rectangular Material: Brass Type and theme of the motif: Inscription (name of tool-maker, Abd al-Aima, Abjad numerals, names of cities, numbers 1 to 14, Babylonian hours, Arabesque motifs Decorative techniques: Engraving Location: Unknown, https://Ancient point.com access date (2/12/2020)
		Material: Rectangular Material: Brass

Image	Sample Decoration	Description
	 	Type and theme of the motif: Inscription (name of tool-maker, Abd al-Aima, Abjad numerals, names and inclination of cities, main directions, numbers 1 to 14), Arabesque plant motifs. Construction date, 11th and 12th century A.H. Decorative techniques: Engraving Location: Sotheby's Auction, http://sothb'ys.com access dats(21/3/2020)
	 	Material: Rectangular Material: Brass Type and theme of the motif: Inscription (Phrase «یا صانع» in a medallion, Abjad numerals, names of cities, numbers 1 to 14, Zahor script. Name of tool-maker, Abd al-Aima, Construction date, 11th and 12th century A.H. Decorative techniques: Engraving Location: http://sothb'ys.com access dats (21/3/2020)

Conclusion

The social, cultural, and religious background that emerged during the Safavid period led to the expansion of astronomy and, accordingly, the construction of all kinds of instruments and equipment required by this science. Astronomical instruments were made by skilled and expert artists and artisans in large sizes for observatories and in smaller and portable sizes for the personal use of astronomers and scientists. In the current research, 35 non-observational instruments, including a celestial sphere, Qiblanama (Qibla compass), compass, and sundial belonging to the Safavid period, were examined from the perspective of materials, motifs, techniques, and decorative issues. The identified celestial spheres have the same appearance and are all made of brass. The most common motifs are inscriptions and human-animal motifs of constellations and astrological signs, the name of the tool-maker, and the construction date, which were created on the spheres with the methods of engraving and silvering (to display the position of the stars better). In the Safavid period, due to the expansion of science and culture and the emergence of proficient calligraphers, in addition to the Kufic script, Naskh, Thuluth, and especially Nastaliq scripts were also used on various objects such as astronomical instruments. With the beginning of the Shiite government of the Safavid religion, many Qiblanama (Qibla compass) and compasses were made compared to the previous periods. In this era, these two instruments were sometimes combined and produced in the form of one instrument. Perhaps the reason for the prevalence of the manufacture and production of these items in the Safavid period can be seen in the considerable expansion of commercial and political relations, the increase in travel and the prosperity of deeper connections with Europeans, and the popularity of these items as gifted items. The compasses of this period are all made of brass, silver, and bronze in a circular shape and with considerable variation compared to the past. In addition, inscription motifs with Thuluth, Naskh, and Nastaliq scripts, including prayer statements, Persian poems, Abjad numerals, the names of cities and the degree of their inclination from Mecca, the four main directions, the name of tool-maker and plant motifs have been used on the margins of these instruments. These motifs are created with engraving, latticework, and stone-loading techniques. Sundials are made of brass and sometimes of stone in two circular and

rectangular shapes. Their most decorative motifs are inscriptions including the name of the tool-maker, Abjad numerals, the names of cities, numbers 1 to 14, and 4 main directions, which in some cases are accompanied by Arabesque motifs on the margins. Also, the use of the Sun motif in some sundials is a reminder of the application of these objects. The scripts of Thuluth, Naskh, and Nastaliq (especially in the writing of Persian poems) have been used the most on these objects, and the most widespread decorative techniques used in sundials have been engraving. In addition, in some cases, Roman numerals have also been observed. The application of Roman numerals by Persian artisans and artists in some of these clocks can be seen as a sign of the cultural influences caused by the presence of Europeans and the importation of European clocks or the ordering of their manufacture by Europeans. In general, it can be said that apart from the celestial spheres, most of the non-observational instruments have had personal use, and some of their types, especially the Qiblanama (Qibla compass), compass, and sundials, have been used by a group of people who were not necessarily astronomers and astronomy scientists.

Research Suggestions

Undoubtedly, the present study is the first step toward a deeper understanding of non-observational instruments. The generalization of this research in future research focused on the early and later Islamic centuries can provide a general view of the evolution and the complete process of construction, production, and characteristics of these instruments in the Islamic era.

Author Contributions

This article is taken from author 1's thesis entitled "Investigation of Tanjim tools from the Ilkhanid period to the end of Safavid period" under the guidance of author 2 at Shahrekord University. This manuscript was written with the participation of all authors. All authors discussed the results, reviewed and approved the final version of the manuscript.

Acknowledgment

Not applicable.

Conflict of Interest

The author (s) declare that there are no potential conflicts of interest related to this research, in writing, and publication of this article.

Research Funding

The author (s) did not receive any financial support for conducting the research, writing up, and publication of this article.

Appendix

1. Astrolabe: It is one of the most important instruments in astronomy with various applications. The following is stated in Kashf al-Zunun about the astrolabe: «An instrument that is often used for astronomical tasks, such as determining the height of the Sun, knowing the length and width of the land, knowing the height of mountains and the width of rivers according to the principles and laws stipulated in it» (Afrough & Norozi Talab, 2012).
2. (Rob') Quarter: Rob' is the name of a group of astronomical instruments that are called Rob' (quarters) because of their 1/4 circular shape (Giahi Yazdi, 2009, 202).

3. Zat al-sho'bateyn: Three rulers which are placed on a base (Korsi) and by which they determine the height. This instrument is considered to be one of Ptolemy's inventions. (Faqih Abdolahi, 1995).
4. Zat al-Samt va al-Ertefa': It was an instrument with which they measured the coordinates of the direction and height of celestial bodies (Giahi Yazdi, 2009, 52).
5. Zat al-Halaq: It was made from 5 to 9 circles (usually 7) depending on the requirements, and it was used to represent the important celestial circles (Gyahi Yazdi, 2009, 208). Zat al-Halaq has been mostly used for locating, observing, and investigating the movements of the planets (Mozaffari, 2009).
6. Sods: This tool, like Rob' (Quarter), was used to measure the height of celestial bodies, especially the Sun (Gyahi Yazdi, 2009, 211).
7. The change of Qibla from Bayt al-Muqaddas (the first Qibla of Muslims) to Mecca is mentioned in the tenth verse of Surah Al-Baqarah (from verse 142 to 151) (Raja', 2013, 408-415).
8. Making observational and astronomical instruments, all kinds of clocks and means of identifying prayer times have been common in all Islamic countries, and before the Mongol conquest, the two main Islamic centers of the East, namely Alamut (the center of the Ismaili religion) and Baghdad (the capital of the Abbasid caliphs), tried very hard to collect such instruments and attract masters of these techniques. After Hulegu reached Alamut and Baghdad, most of the astronomical instruments were given to Khwaja Nasir al-Din Tusi to use them in the Maragheh observatory. In addition, during his trips to Baghdad, Khawaja himself collected some other such tools to carry out observations and took people who were familiar with the industry of observational and astronomical instruments to Maragheh with him (Iqbal Ashtiani, 2008, 564-565).
9. Cartography in a general sense refers to all map preparation operations, including field and office operations, and in a special sense, it includes the art of mapping or drawing maps and charts (Jafari, 1997, 275).
10. On these clocks, lines carrying hour lines were drawn for horizontal dialing counting from sunrise to sunset based on Babylonian clock numbers 1 to 14 (Sotheby's website).

References

- Afrough, M. & Norozi Talab, A. R. (2012). Survey and analyzing astronomical concepts as the shape and decorative images in metal works of the Seljuk period: A case study of Abriz Berenji. *Negreh Journal*, 7(21), 69-84. **[In Pesian]**
- Afrough, M. (2014). Astrolabe (Introducing the astrolabes of Master Abd al-Hossein Abd al-Aima). *Journal of Iranian Studies*, 13(25), 25-45. DOI: 10.22103/JIS.2014.947 **[In Pesian]**
- Aram, A. (1987). *Science in Islam*. Tehran: Soroush. **[In Pesian]**
- Bagheri, M. (2014). List of sundials of Iran. *Islamic Scientific Heritage*, (1), 49-72. **[In Pesian]**
- Bayani, Sh. (2000). *The Mongols and Ilkhanid Rule in Iran*. Teharn: SAMT. **[In Pesian]**
- Biruni, A. (2009). *التفيم لأوائل صناعه التنجيم (Interpretation of the pioneers of the astrology industry)* (by Jalaluddin Homaei). Tehran: Publications of the Association of National Artifacts. **[In Pesian]**
- Bouvat, L. (2005). *History of the Mongol «Timorids»* (M. Behfrouzi, Trans.). Tehran: Azadmehr. **[In Pesian]**
- Boyle, J. A. (2001). *History of Iran (from the arrival of the Seljuks to the collapse of the Ilkhanid government)* (H. Anousheh, Trans.) (Volume 5). Tehran: Amir Kabir. **[In Pesian]**
- Chardin, J. (1959). *Chardin's travelogue* (M. Abbasi, Trans.) (Vols 2 & 5). Tehran: Amir Kabir Study Institute. **[In Pesian]**
- Dehkhoda, A. A. (1998). *Loghat nameh.* Tehran: University of Tehran. **[In Pesian]**
- Ehsani, M. T. (1989). *Seven thousand years of metalwork art in Iran.* Tehran: Scientific and Cultural Publications. **[In Pesian]**
- Ehsani, M. T. (2011). *Seven thousand years of metalwork art in Iran.* Tehran: Scientific and Cultural Publications. **[In Pesian]**
- Esfandiari Mohani, Z. (2018). Analysis of astronomers' position in society and the rule of the Safavid era. *Journal of Iranian Studies*, (34), 1-26. Doi: 10.22103/JIS.2018.9107.1647**[In Pesian]**

- Faqih Abdulahi, H. (1995). Review of Ghiyathuddin Jamshid Kashani's treatise describing observation instruments. *Islamic Research*, (1 & 2), 277-318. **[In Pesian]**
- Ghazni, S. (1977). *Astrolabe or astronomical counter*. Tehran: Ministry of Science and Higher Education. **[In Pesian]**
- Giahi Yazdi, H. R. (2009). *History of astronomy in Iran*. Tehran: Cultural Research Office. **[In Pesian]**
- Habibi Qaeini Beygi, M. (2009a). Astronomy treasure of Astan Quds Razavi. *Organization of Libraries, Museums, and Document Center of Astan Quds Razavi*, 1(3), 1-30. **[In Pesian]**
- Habibi Qaeini Beygi, M. (2009b). Horology and clock with a look at the Astan Quds Razavi clock museum. *Organization of Libraries, Museums, and Document Center of Astan Quds Razavi*, 1(4), 1-28. **[In Pesian]**
- Hasanzadeh Amoli, H. (1993). Compass and Qiblanama (on the difference between the geographic pole and the magnetic pole of the Earth and the knowledge of the direction of the Qibla from the compass and distinguishing the compass from the Qiblanama. *Waqf, Eternal Legacy*, 2(2), 86-97. **[In Pesian]**
- Hogendijk, J. P. (2012). The secrets of Isfahan's Qibla compasses (S. Farrukhnahad, Trans.). *The Heritage of Islam and Iran*, 1(1), 21-35. **[In Pesian]**
- Iqbal Ashtiani, A. (2008). *Mongol history*. Tehran: Negha Publishing House. **[In Pesian]**
- Jafari, A. (1997). *Encyclopedia of geography* (Geographical Terminology). Tehran: Gitashenasi Publications. **[In Pesian]**
- Kennedy, E.S. (2000). *History of Iran* (Timurid Period), Cambridge University Research (Y. Ajand, Trans.) (Vol 6). Tehran: Jami. **[In Pesian]**
- Khalili, N. (2008). *Collection of Islamic art (Scientific instruments)*. Tehran: Amir Kabir. **[In Pesian]**
- King, D. & Saliba, G. G. (1972). The Abd al-Aima Astrolab Eforgeres. *Journal for the History of Astronomy*, 2(3), 188-198.
- King, D. A. (1996). Science in the service of religion: Islam (T. Heydarzadeh, Trans.). *Farhang*, (20 & 21), 197-225. **[In Pesian]**
- Kolahkaj, M. & Esfandiari Qorabi, N. (2021). Recognizing the layering wall decorations of Safavid palaces in Isfahan and its regeneration for newer usages. *Paykareh*, (23), 74-60. **[In Pesian]**
- Mashkourian, M. T. (2016). *Investigation and analysis of the components of the chronological system of the Iranian Safavid society* (Doctoral Dissertation in History). Faculty of Literature and Humanities, Isfahan University, Isfahan, Iran. **[In Pesian]**
- Mozaffari, S. M. (2009). Observatories of the Islamic world. *Monthly Book of Science and Technology*, (113), 71-60. **[In Pesian]**
- Nabaei, A. (1986). Identifying the most exquisite astrolabe in the world. *Mishkat*, (12 & 13), 158-173. **[In Pesian]**
- Ohashi. Y. (2008). Introduction of Persian astronomy in India. Tarikh e Elm Iranian. *Journal for the History of Science*, 1(6), 49-74.
- Raja, A. A. (2013). *Change of Qibla, Encyclopedia of Hajj and the two holy shrines* (Vol 5). Tehran: Mashaar Publishing House. **[In Pesian]**
- Roohfar, Z. (1996). Astrolabe, celestial sphere, and cupping horn (Shakh Hejamat) (introduction of some exquisite instruments from the National Museum). *Waqf, Eternal Legacy*, 5(15 & 16), 86-84. **[In Pesian]**
- Saeidnia, A. (2008). The secret of the clock stone of the Imam Mosque (Shah Abbasi) in Isfahan. *Journal of Fine Arts*, (35), 5-14. **[In Pesian]**
- Sepehri, J. (2008). Amazing developments: Inventions and initiatives of Iranians in the field of navigation and astronomy. *Monthly Book of Science and Technology*, 104(16), 92-93. **[In Pesian]**
- Shami, N. (1984). *Zafarnameh* (M. A. Panahi, Edit.). Tehran: Bamdad. **[In Pesian]**

- Tavernier, J. B. (2010). *Tavernier's travelogue* (H. Arbab Shirani, Trans.). Tehran: Niloufar. **[In Pesian]**
- Varjavand, P. (2005). *Exploration of Maragheh observatory and a look at the background of astronomy science in Iran*. Tehran: Amir Kabir. **[In Pesian]**