TÜRKİYE CUMHURİYETİ
CUMHURBAŞKANLIĞI

KUZEY KIBRIS TÜRK CUMHURİYETİ
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MİLLET KÜTÜPHANESİ

History of Turkish - Islamic Science

in 100 Objects

November 15, 2021 - February 28, 2022

Lefkoşa

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PRESENTATION

Knowledge is an ancient power that benefits all of humanity. No doubt, all civilizations have contributed to the gradual accumulation of this power. Yet, Islamic civilization has had a particularly big role in laying the foundations of the current state of science and technology.

From medicine to astronomy, many technological developments, have flourished across the Islamic geography. Therefore, the assumption that science started in the West and spread to the world from there is a blindfold that hides the truth.

According to a Euro-centric view of the world and history, the Middle Ages are a dark period. However, in the Islamic geography, that same period was characterized by the enlightenment brought by scientific studies. In this sense, the Western world owes the basis of the enlightenment and the scientific revolution it experienced to the horizon of ideas opened by the Islamic civilization.

The religion of Islam is a call that invites people to admire the creation, that encourages them to contemplate, and awakens the faculty of discovery in humans by reflecting on the secrets of the universe; in brief, it is a call that helps develop human potential to its highest level. Many verses and hadiths, such as hadith-i sharif "Seeking knowledge is an obligation on every Muslim, man or woman," have been the main driving force and main principle in our civilization's quest for scientific exploration.

This has enabled the emancipation of ideas in the basin of Islamic Civilization without being held up by the shackles of superstitions, and let them travel freely from the earth to the eternity of the universe. Discoveries made in fields such as astronomy, mathematics, chemistry, biology, physics and medicine have become a legacy for all humanity.

We opened the Museum of Islamic Science and Technology in the old Has Stables Building in the Gülhane Park under the leadership of the late Professor Fuat Sezgin with the goal of introducing this heritage to new generations.

This exhibition housed in the Nation's Library at the Presidential Complex, includes the re-productions of some of the works prepared by the late Professor for the History of Science and Technology Museum, as well as 13 manuscripts on the subject.

Both the museum in Istanbul and the exhibition in the Nation's Library as well as exhibition at Lefkoşa North Cyprus will connect the experience of the extraordinary ages we have been through with both the present and the future, and will serve as an important landmark for reinforcing the perceived continuity of time.

For members of a civilization that has its mind set on the skies, extended its reason towards the eternity of the universe, and filled the earth with observatories, madrasas and hospitals, remembering this past is not only a source of pride but also a reference point in drawing up our roadmap for the future.

I believe that those who turn their backs on this great wealth simply because it bears Islam and Turkish in its name, will one day realize that the developments they envy and aspire to are in fact underpinned by their own civilization.

I would once again like to commemorate our ancestors who spent each day of their lives serving the humanity with appreciation and gratitude. I would like to congratulate those who have contributed to the preparation of the exhibition both the Nation's Library, and Lefkoşa North Cyprus extend my gratitude to our visitors.

Recep Tayyip ERDOĞAN
Turkey President

PRESENTATION

Every civilization creates its own cultural structure with what it produces. These include the traces of previous eras and are symbolic representations of those eras. Elements that give birth to civilization are the values people exhibit such as philosophy, literature, art and architecture.

The Islamic civilization emerged as a harmonious synthesis of mind and emotion. The most important distinctive quality of the Islamic civilization is its contribution to development of all sciences. In the holy book of İslam, Quran, “science” and words derived from “science” appear 750 times.
Muslims achieved great discoveries in the fields of religion-philosophy, science-art, as well as the technical sciences. These discoveries contributed to the progress of other civilizations including the european countries.

Throughout history, original works of many Islamic scholars have shed light on the whole world. The works of Ibn Sina, who established a perfect philosophy system that dominated the tradition of Islamic philosophy for centuries. Ibn Sina's book on Medicine (Cannon of Medicine) was used as the main textbook in European medical schools for about 600 years.
Likewise, Ibn Khaldun has been accepted as the founder of sociology by many European scientists, and his work named “Mukaddime” has left deep traces on world science.

Here, I commemorate the deceased Prof Dr Fuat Sezgin, who devoted his life to researching Islamic science, traveled the world step by step and classified hundreds of different manuscripts, and most importantly, succeeded in proving that science emerged in islamic societies and spread through Islamic civilization.

Islamic Civilization inherently has a dynamic and developing power that determines the direction of change and moves towards its desired goal.
From the Turkish Republic of Northern Cyprus, which is a part of the Islamic geography, from this ancient land left to us by our ancestors, I sincerely congratulate those who contributed to the preparation of the History of Turkish/Islamic Science Exhibition.

Ersin Rüstem TATAR
TRNC President

INTRODUCTION

Science, which owes its progress to interactions among civilizations throughout history, is a living phenomenon and the common heritage of all humanity. Tracing the course of science in history is essential for putting together the pieces of the puzzle to arrive at a holistic view. Using some of the pieces and neglecting others causes scientific data to become fragmented and decontextualized.

Although it has been ignored and overlooked for many years, the Islamic civilization made great contributions to world culture and science over a period of approximately eight centuries (8th century - 16th century AD). In the last 50 years, studies on the history of Islamic science have gained momentum, thus the Eurocentric discourse that prevails in the West and marginalizes the contributions of Islamic civilization to science has slowly begun to change.

The most important contribution towards unearthing the Islamic scientific heritage has been undoubtedly done by the late Prof. Fuat Sezgin. While he traced Islamic manuscripts on the subject of science all over the world and prepared a monumental collection of bibliographic works, he has also accessed, classified and published hundreds of works written since the 19th century on the history of Islamic science.

Perhaps the most important contribution of Prof. Fuat Sezgin to the world of history of science, apart from all his scientific works, is that he re-produced the inventions described in hundreds of different manuscripts or articles, and collected them in a single collection. A revolution in itself for making the heritage of Islamic science visible, this collection will now be on display in Ankara, following its showcasing in Istanbul.

100 objects from this rich collection were carefully selected for the exhibition titled "History of Islamic Science in 100 Objects" prepared on the occasion of Ramadan. The objects were selected with a view to determining "top" categories of the history of science, while also taking the technical, chronological and geographical diversity into consideration.
For example, the astrolabe collection selected for the exhibition includes the oldest, most advanced and most beautiful examples worldwide, as well as a special astrolabe made by a Sultan himself. Alongside this, many valuable scientific objects are a part of the selection including a wide range of objects from the grab dredger of the Banū Mūsā brothers who lived in Baghdad in the 9th century to the 6-cylinder water pump designed for the first time by the Ottoman scholar Mohammad b. Ma'ruf al-Mişrī ar- Raṣṣad Taqīyaddīn, who carried out extremely important scientific studies in Istanbul in the 16th century.

The "History of Islamic Science in 100 Objects" exhibition held at the Nation's Library of the Presidency of the Republic of Turkey and then in Lefkoş, North Cyprus features a pioneering modern exhibition design to showcase this special selection that has reached our present day from the pages of the history of science, accompanied by a special ambiance that appeals to contemporary visitors. For the first time, the source manuscripts describing these instruments accompany the re-cast instruments in the exhibition, and the surviving autograph copies of some of the scholars who invented these instruments are also included in the exhibition.

Visitors to the exhibition will be able to study the manuscript introducing the instruments used in the Istanbul Observatory with miniature paintings produced in the same period along with the observation instruments invented by the celebrated engineer and inventor Mohammad b. Ma'ruf al-Mişrī ar-Raṣṣad Taqīyaddīn for Istanbul Observatory. They will also be able to see the draft autograph copy penned by Taqīyaddīn based on his observations at the observatory and become a witness to the first lines written by the scholar.

The design aims to create the feeling of witnessing one of the leading astronomers in world history of science "on the job".

The exhibition catalogue for "History of Islamic Science in 100 Objects" prepared in accordance with the most up-to-date literature and new photographs has refrained from offering overly technical information, yet presents scholarly references for those who would like to learn more. The Catalogue covers astronomy, geography and navigation, clocks, geometry, optics, technics, chemistry and medical fields in this order. The section on astronomy is the longest one and covers observatories, standard, spherical, universal and quadrant astrolabes, equatoria and other astronomical instruments. The section on geography covers maps, compasses and ships; the section on clocks describes different solar, water, and candle clocks, as well as mechanical clocks. The part about geometry covers various instruments used in the field of geometry and the part on optics describes the instruments and experiment setups developed by Islamic scholars to use in optical research. The technical section presents practical inventions such as water pumps, levers and lock mechanisms. The part on chemistry features larger chemical production tools used in industrial manufacturing in addition to chemical laboratory instruments. Finally, the part on medicine introduces instruments developed for measuring the quantity of blood drawn as well as surgical instruments used in many types of surgical interventions.

It is impossible to think of discoveries, inventions and similar scientific developments independent of history, the present day, society and practical applications. It is a fact that knowledge and technologies used in daily life have an ancient history, yet they continue to evolve; the transfer of accumulated knowledge, self-confidence and wisdom from the past can help create a strong presence in the world of sciences in the future. Therefore, this exhibition and catalogue aim to present concrete examples of scientific and technical contributions of Islamic civilization to world history and create an awareness about them among visitors and readers.

We hope that this comprehensive effort which is a pioneer in terms of the up-to-date academic literature it builds on and the modern exhibition methodology used in the exhibition will reach groups that go beyond those we have aimed and imagined and that they create the same, if not more, enthusiasm among its interlocutors. Our goal is to ensure that the knowledge of the history will shed light on a new understanding of the present and create a vision that will guide the future on a solid foundation.

Hüseyin Şen
Curator

Astronomy

OBSERVATORIES

ASTROLABES

EQUATORIA

MECHANICAL INSTRUMENTS

01 MARAGHA OBSERVATORY AND ITS GREAT SEXTANT

The construction of the Maragha Observatory, which is one of the most important observatories established in the history of Islamic civilization, started just one year after the Mongol ruler Hulagu Khan's conquest of Baghdad (657/1259) and the famous scholar Naṣīraddīn aṭ-Tūsī (d. 672/1274) was personally charged with this task.[1]

The central tower with a radius of 10 to 12 meters and a diameter of 28 meters was the most important structure in the observatory built on a hill about 80 km south of Tabriz. Apart from the tower, there were other small structures housing observation instruments in this center.

Apart from Naṣīraddīn aṭ-Tūsī, there were many other scholars working in this observatory such as Abi š-Šukr al-Maġribī, Mu'aiyadaddin al-'Urḍi, Aṯīraddin al-Abharī, Nağmaddīn Dabīrān and Faḫraddīn al- Ḫīlāṭī.[2]

Another interesting figure known to be working in the observatory was Ibn al-Fuwaṭī. Discovered by Naṣīraddīn aṭ-Tūsī and employed as a librarian at the Maragha Observatory, al-Fuwaṭī worked in the observatory for about 20 years and continued to work at the Madrasa al-Mustanṣirīya in Baghdad as of 1280. Al-Fuwaṭī, who met hundreds of scientists during his post in Maragha, made notes about the scholars he met. He later wrote a work of five volumes using these notes. Of these five volumes, only two have survived to the present day, and even those constitute a very important and interesting source about the period.[3]

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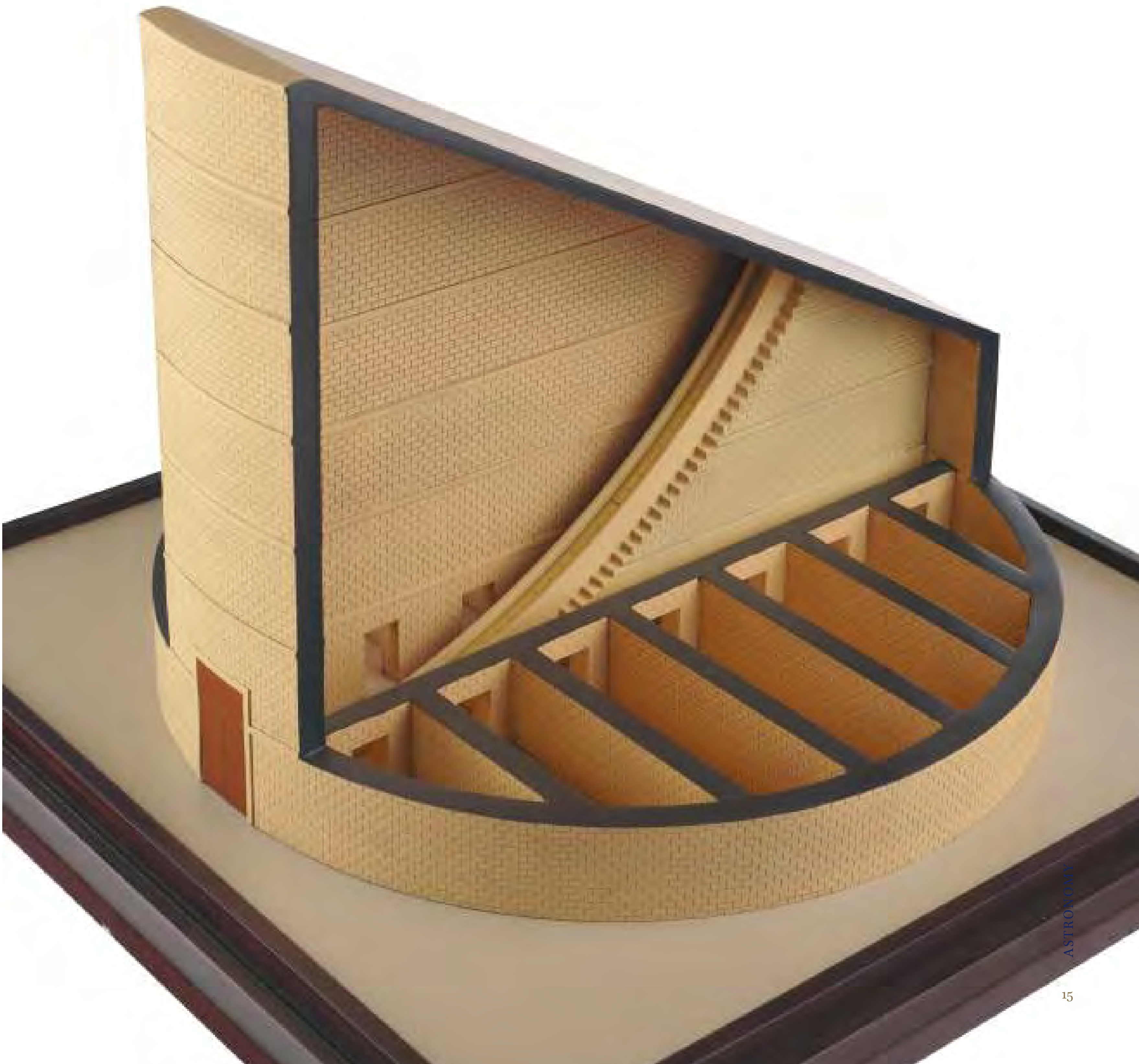
1 For detailed information about the observatory, see: Aydın Sayılı , *The Observatory in Islam*, Türk Tarih Kurumu Yayınları, Ankara 1988, pp. 187- 228; Salim Aydüz, "Rasathâne", *DİA*, Türkiye Diyanet Vakfı Yayınları, Istanbul 2007, Vol. 34, p. 457, Fuat Sezgin, *İslam'da Bilim ve Teknik*, Kültür Bakanlığı Yayınları, Ankara 2007, Vol. 2 H. 32.

2 Sayılı, *The Observatory in Islam*, p. 205.

3 Franz Rosenthal, "Ibn al-Fuwati", *Encyclopaedia of Islam, Second Edition*, Brill, Leiden, Vol. 3, pp. 769-770; Cengiz Tomar, "el-Fuvātī", *DİA*, Türkiye Diyanet Vakfı Yayınları, Istanbul 2007 , *Vol.* 21, pp. 47-49.



OBSERVATION INSTRUMENTS IN THE MARAGHA OBSERVATORY:

02 THE INSTRUMENT WITH THE TWO QUADRANTS BY MU'AIYADADDIN AL-'URḌI

One of the astronomers working at the Maragha Observatory was Mu'aiyadaddin al-'Urḍi. 'Urḍi invented some of the instruments in this observatory. He describes the instruments made for the Maragha Observatory in 1260 in his work titled *Kaifīyat al-arṣ*ād *wa-mā yuhtāğu ilā* 'ilmihī. One of these instruments is the instrument with the two quadrants (al-āla dhāt ar-rub'ain) that he developed himself, which was used to measure the altitude and azimuth of the stars. In his work on this instrument, he writes:

I say that this instrument eliminates the need for the armillary sphere. It is obvious that it is easier to make and to use, and that it is more accurate. By using this instrument, we are able to measure many things that we cannot achieve with the armillary sphere, however it is also true that working with this instrument does not eliminate the need for calculation in all matters except altitude.[4]

He thus emphasizes the superiority of this instrument he developed over the observation instrument invented by Ptolemy and known as "dhāt al-ḥalaq" in the Islamic world; he continues:

Yet this instrument is more perfect and easier to make. With this, geographic latitude measurement can be made in two ways. First, from the meridian altitudes of the Sun (*in summer and winter solstices*)*; second, from the lower and upper meridian altitudes of the stars that never set. This is something that is impossible to obtain from the armillary sphere. Surely, all these are by the will of Almighty Allah.*[5]

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4 Sevim Tekeli, "Al-'Urdî'nin 'Risaletün fî Keyfiyyeti'l-Ersâd'ı", *Araştırma*, Vol. 8, 1972, pp. 1-171., Sezgin, *İslam'da Bilim ve Teknik*, p. 44.

5 Tekeli, "Al-'Urdî'nin 'Risaletün fî Keyfiyyeti'l-Ersâd'ı", p. 40.

OBSERVATION INSTRUMENTS IN THE MARAGHA OBSERVATORY:

03 THE PERFECT INSTRUMENT OF MU'AIYADADDĪN AL-'URḌĪ

In his work titled *Kaifīyat al-arṣād wa-mā yuhtāğu ilā* ʿilmihī, Mu'aiyadaddīn al-ʿUrḍī expressly writes that some of the instruments used in the Maragha Observatory are his own invention. One of these is the instrument he calls the Perfect Instrument. According to Mu'aiyadaddin al-ʿUrḍi, this instrument is a new version of the al-āla al-Kāmila, which he had previously constructed for the ruler of Homs (Syria) in 650/1252.[6]

Mu'aiyadaddīn al-ʿUrḍī compares these instruments of his own invention with those in the Almagest, the masterpiece of the Greek astronomer Ptolemy, and emphasizes the superiority of his inventions as follows:

It is obvious that it is possible to examine many problems, which are also mentioned in the Almagest but could not be addressed there, with the help of these instruments we have derived from it. With this, for example, the unknown location of any star can be found by means of a (another) star whose location is known at latitude and longitude. That is, if we can measure the altitude and the azimuth of any star with this instrument, we can also obtain the heliacal rising. Subsequently, if we measure the altitude, azimuth and heliacal rising of the star with an unknown location, the location of the star will be obtained in latitude and longitude. If this is derived from al-āla dhāt ar-rubʿain, the result will be more precise as the altitude of both will be obtained at the same time. Surely all this is with the consent of Almighty Allah. As for the triquetrum in the Almagest, it results in an error compared to what is achieved with the instruments (we built).[7]

Our model was built according to the description and drawings in the work.[8]

6 Tekeli, "Al-ʿUrdî'nin 'Risaletün fî Keyfiyyeti'l-Ersâd'ı", p. 51.

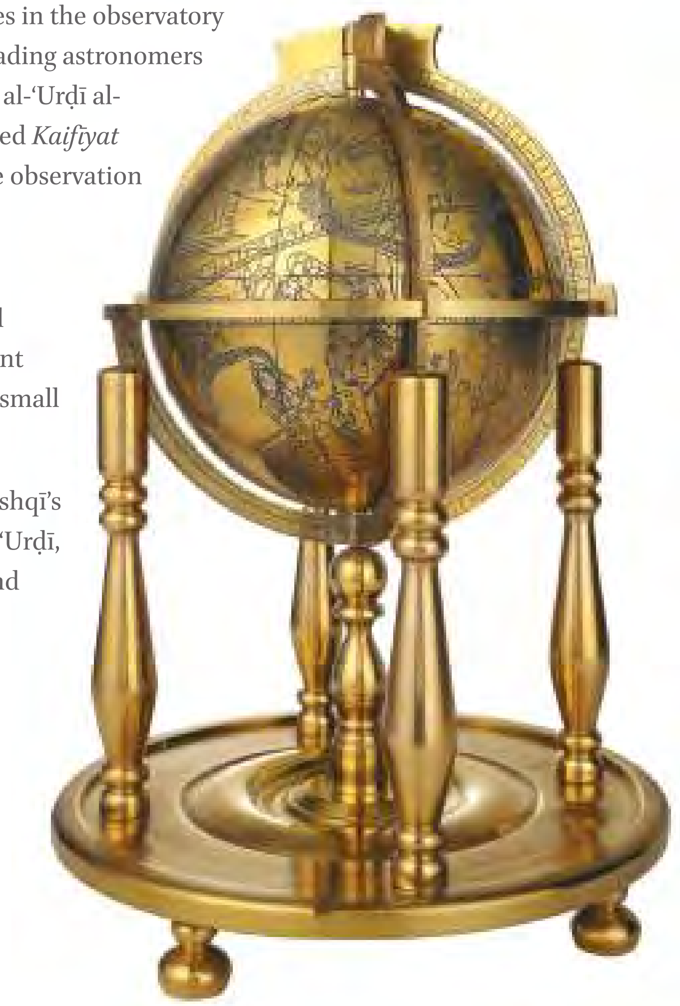
7 Tekeli, "Al-ʿUrdî'nin 'Risaletün fî Keyfiyyeti'l-Ersâd'ı", pp. 54-55.

8 Sezgin, *İslam'da Bilim ve Teknik*, pp. 50-51, pp. 50-51.

THE ONLY OBJECT THAT HAS SURVIVED FROM THE MARAGHA OBSERVATORY TO THE PRESENT DAY:

04 DRESDEN SPHERE

Founded by the order of the Mongol ruler Hulagu Khan in Maragha, about 50 miles south of Tabriz, the Maragha Observatory where Naṣīraddīn aṭ-Tūsī was appointed as the director, was one of the most important observatories in Islamic civilization. Important scholars of the period worked in this observatory and the activities in the observatory continued at least until 1304.[9] One of the leading astronomers working in the observatory, Mu'aiyadaddīn al-'Urḍī al-Dimashqī, wrote a very important work titled *Kaifīyat al-aṣ*ād *wa-mā yuhtāǧu ilā* ʿilmihī about the observation instruments used in the observatory.



Unfortunately, nothing has survived of this observatory except for some archaeological remains of the building. The only instrument that has survived from the observatory is a small celestial globe made of brass.[10]

Crafted by Mu'aiyadaddin al-'Urḍī al-Dimashqī's son, Muḥammad ibn al-'Mu'aiyadaddīn al-'Urḍī, this celestial globe has 48 constellations and 1025 stars.

This sphere, which reached Dresden in the 16th century, is one of the most important instruments in the Mathematics-Physics Hall of the Dresden State Art Collections (Dresden Staatliche Sammlungen) today.[11]

Our model is based on the original in this museum.[12]

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9 Sayılı, *The Observatory in Islam*, p. 212.

10 For detailed analysis and drawings of the globe, see: Adolp Drechsler, *Der Arabische Himmels-Globus angefertigt 1279 zu Maragha von Muhammad bin Muwajid Elardhi zugehörig dem Königlichen mathematisch-physikalischen Salon zu Dresden,* Königl. Hofbuchhandlung von Hermann Burdach, Dresden, 1873. See also: Günther Oestmann, "Measuring and dating the Arabic celestial globe at Dresden", *Scientific Instruments and Museums: Proceedings of the XXth International Congress of History of Science,* (Liège, 20-26 July 1997), Vol. XVI, Brepols, Turnhout 2002.

11 For an image of the original object, see: https://skd-online-collection.skd.museum/Details/Index/50250.

12 Sezgin, *İslam'da Bilim ve Teknik*, p. 52.

05 THE SAMARKAND OBSERVATORY

The Samarkand Observatory, established by Timur's grandson Mīrzā Muhammad Tāraghay bin Shāhrukh Uluġ Beg (796-853 / 1394-1449) is among the most significant observatories in the history of Islamic astronomy.[13] According to the sources of the time, its founder Uluġ Beg was a very successful and intelligent scholar in addition to being a ruler.

In a letter he wrote to his father, which has survived to our day by pure chance, the famous Islamic scholar Ǧamšīd el-Kāšī , who worked in the service of Uluġ Beg at the Samarkand Observatory, describes Uluğ Beg as follows:

``... *Thanks to Allah and His blessings, the sultan of Islam, who rules in seven climates, is a scholarly person. May God perpetuate his state and sovereignty. I am not saying this word out of courtesy. Indeed, he knows most of the Quran by heart. He remembers the statements of the commentators about each verse verbatim. He quotes from them on all suitable occasions. He reads two parts from the Qur'an fluently and in full compliance with the rules in the presence of Qur'an memorizers every day. He has never made a mistake. He has a very good knowledge of Arabic language and grammar, and his Arabic composition is excellent. Likewise, his knowledge of jurisprudence is deep and he is proficient in logic and literary arts and methods* (*the principles of prosody*).

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13 For detailed information about the Samarkand Observatory, see: Salim Aydüz, "Semerkant Rasathanesi", *DİA*, Türkiye Diyanet Vakfı Yayınları, Istanbul 2007, Vol. 36, p. 486, 487. See also: İhsan Fazlıoğlu, "Osmanlı felsefe-biliminin arka planı: Semerkand matematik-astronomi okulu", *Divan: Disiplinlerarası Çalışmalar Dergisi,* 14 (2003), pp. 1-66.

When it comes to various branches of mathematics, he has gained great skill in these and this skill has reached such a level that one day, while riding a horse, for a date known to have coincided with a Monday between the tenth and the fifteenth day of the month of Rajab of the year eight hundred and eighteen, he wanted to mentally calculate the corresponding date in the Solar calendar; for this, while still on the horse, he calculated the longitude of the sun corresponding to that day with a precision down to two minutes and asked me the result when he got off the horse.

It is necessary to keep some numbers in mind in mental calculation and to do the calculations based on them. Yet our memories are deficient. For this reason, he could not calculate the result (accurately) in degrees and minutes, he limited himself to degrees. But no one among today's people are capable of doing this; no one is blessed with such skill in mental calculation.

In short, he has very profound skills in mathematical sciences, he writes the proofs of current methods in astronomy very well and is competent in the deduction of rules. He teaches so well through the Tadhkira (of Naṣīr al-Dīn al-Tūsī) and Tuḥfa (of Quṭb al-Dīn al-Shirāzī) that no further additions can be imagined."[14]

14 Aydın Sayılı, *Uluğ* Bey *ve Semerkand'daki İlim Faaliyetleri Hakkında Gıyasüddin-i Kâşi'nin Mektubu*, Atatürk Kültür Merkezi Yayınları, Ankara 1991, p. 77.

Uluġ Beg, who gathered pioneering scholars of his time such as Ğamshīd al-Kāshī, Qāḍīzādah Rūmī and Ali Qushjī in this observatory, launched an ambitious observation program and wrote an astronomy book that included updated data obtained through new observations made with these scholars, known as Zīj-*i Sultānī*, *Zīj-i Gūrgānī* or Zīj-*i Uluġ Beg.*

This book is a masterpiece of the history of Islamic science. This work, which is a handbook related to astronomy (Zīj), includes geographical and trigonometric tables that are used to calculate the positions and movements of the Sun, Moon and planets according to different calendars. This is the most important feature that keeps the zīj relevant. Although astronomers working with aṭ-Tūsī at the Maragha Observatory used the data of other pioneering scientists for the Sun, Moon and planetary tables in *Zīj-i* Īlḫānī, these data were calculated on the basis of new observations in the *Zīj-i Uluġ Beg.* Likewise, although the tables of pioneers such as Ibn Yunus and Al-Bīrūnī were used in the *Zīj-i* Īlḫānī for trigonometric tables, these tables were also recalculated with new techniques and more accurate baseline values (such as Sin 1 °) in the *Zīj-i Uluġ Beg*.[15] Calculated at intervals of one arc-minute in this 18-page trigonometric table, these approximate calculations are accurate up to five digits based on sexagesimal numbers, and up to nine digits in the decimal system.[16] Considering that there are 60 arc minutes at each degree and a total of 90 degrees, the fact that a total of 5400 calculations were made for the calculation of this table alone is sufficient to show that this table is a monumental work.[17]

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15 David King, *World Maps for Finding the Direction and Distance to Mecca*, Brill, Leiden 1999.

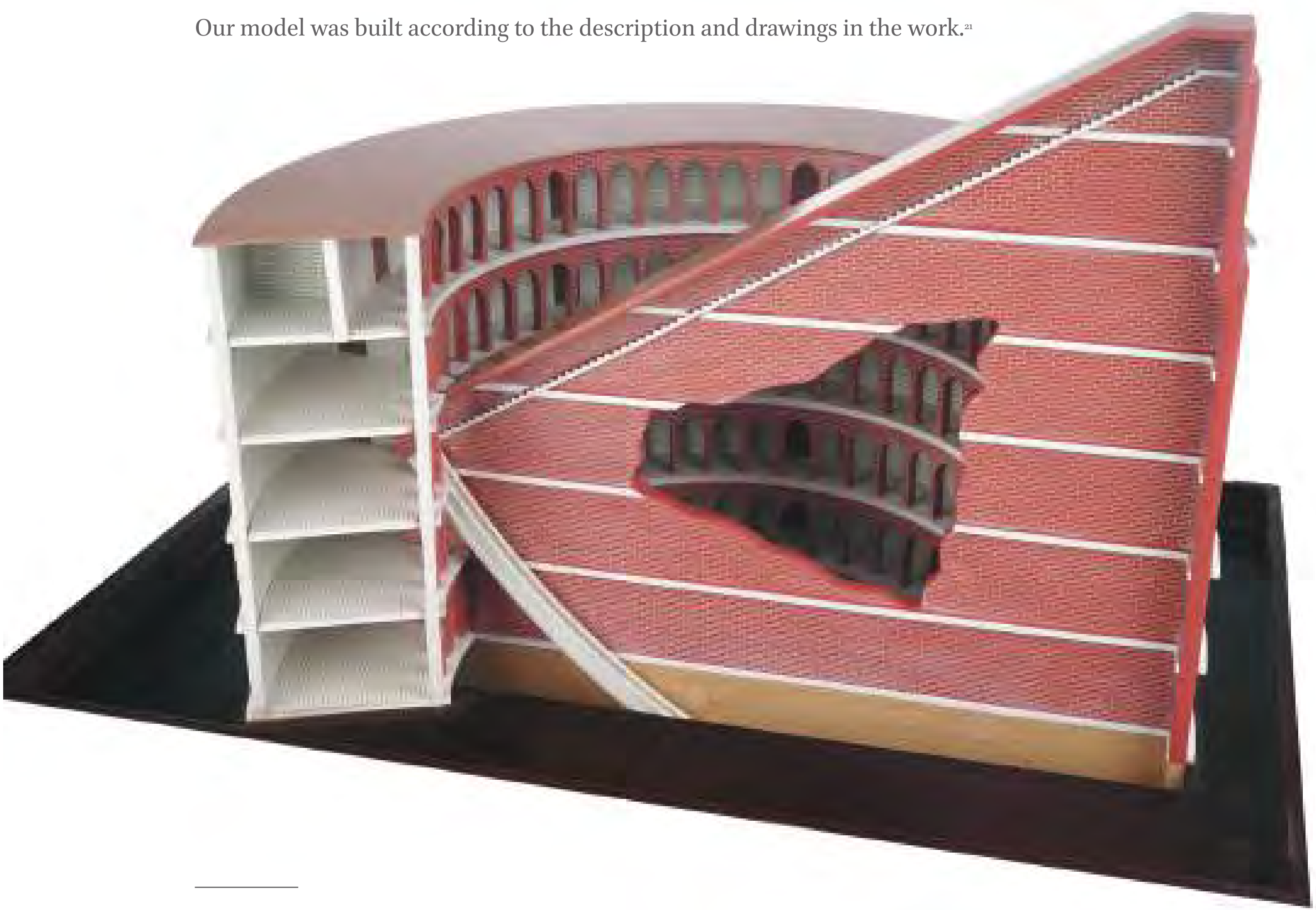
16 Lennart Berggren, *Episodes in the Mathematics of Islam*, Springer, p. 144.

17 Berggren, *Episodes in the Mathematics*, p. 144.

Recently, latitude and longitude coordinates of about a thousand stars in Uluġ Beg's star catalog were transferred to the electronic environment by researchers from Nijmegen and Utrecht Universities in the Netherlands and compared with the catalog of star coordinates measurements made by the European Space Agency's Hipparcos satellite between 1989-1993. It was concluded that Uluġ Beg's table was extraordinarily accurate for that period.[18]

The only instrument that has survived from Uluġ Beg's observatory is an astrolabe preserved in the David Sammlung Museum in Copenhagen.[19] In addition to this, there are manuscripts in various manuscript libraries around the world that were copied for or present in the library of Uluġ Beg. Among these, one of the most exquisite manuscripts is *Ṣuwar al-kawākib aṯ-ṯābita* written by ʿAbdarraḥmān aṣ-Ṣūfī, which is housed in the National Library of Paris.[20]

Our model was built according to the description and drawings in the work.[21]



18 Frank Verbunt & Rob van Gent, *The star catalogues of Ptolemaios and Ulugh Beg: Machine-readable versions and comparison with the modern HIPPARCOS Catalog Astronomy & Astrophysics* 544, A31 (2012).

19 A detailed analysis of this astrolabe has been made by Prof. David King. See: David King, *In Synchrony with the Heavens*, Vol. 2: Instruments of Mass Calculation, Brill, Leiden, 2005, p. XX. For images of the astrolabe on the official website of the museum, see: https: // www.davidmus.dk/files/b/2/406/16.17-D25-1986-forside-Astrolab.jpg and https://www.davidmus.dk/ files / f / 3/390 / 16.17-D25-1986- bagside-Astrolab.jpg

20 BnF Arabe 5036.

21 Sezgin, *İslam'da Bilim ve Teknik*, p. 69.

06 AN OBSERVATION INSTRUMENT INVENTED BY TAQIYADDĪN FOR THE ISTANBUL OBSERVATORY: BEAMED INSTRUMENT

Taqīyaddīn, who was appointed the chief astrologer of the court during the reign of Murad III, established an observatory in Istanbul with the support of the Sultan. Although the exact location and characteristics of the observatory building are unknown, there are some sources about the observation instruments used in the observatory. Among these sources, the most significant ones are the part on "instruments" in *Sidrat Muntahā al-afkār* written by Taqīyaddīn during the time the observatory was active and *Ālāt al-raṣadīya li-zīǧ-i* - Šahinšāhīya written by the Ottoman historian and shahnameh author Seyyid Lokman in Turkish.[22] The work describes nine observation instruments used in the Istanbul Observatory with accompanying miniatures. A study of the descriptions in the work reveals that two of the nine instruments were invented by Taqīyaddīn himself. One of these instruments is the observation instrument called *Ḏāt al-awtār,* namely the "Beamed Instrument".

The purpose of this instrument is to accurately determine the moment (21 March and 21 September) when the spring and autumn equinox, occur. Ptolemy used the instrument called the equatorial ring for this observation, but also warned that the observation made with this instrument quickly gave rise to errors.[23] For this reason, Taqiyaddīn developed a new instrument to carry out the same observation.

In his *Sidrat Muntahā,* Taqīyaddīn states the following about this instrument: "Ḏāt al-awtār: It is one of our inventions. It eliminates the need for the equatorial ring that our predecessors have described. At the same time, it offers information on the changing of the nights and therefore it removes the need for it. In this sense, in recording (observations) it is a purpose that cannot achieve any more perfection..."[24]

Sayyid Lokman says the following on the same instrument: "The two equinoxes, the spring and autumn equinox, are measured and studied with an instrument called Ḏāt al-avtār. Some scholars have arranged a ring for this purpose and placed it parallel to the equatorial plane. For the new observatory, Taqīyaddīn Efendi placed 6 pieces of poles on the rectangular base consisting of 4 legs instead. The four posts are set in a square shape - like the base - and the two posts are erected to set up the struts ... "[25]

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22 Sevim Tekeli, Takiyüddin'in Sidret ül-Müntehâ'sında Aletler Bahsi, *Belleten*, Vol. 25, 1961, pp. 213-238.

23 James Evans, *History and Practice of Ancient Astronomy*, Oxford University Press, Oxford 1998, p. 207.

24 Evans, *History and Practice*, s. 215.

25 Mustafa Kaçar, M. Şinasi Acar & Atilla Bir, *XVI. Yüzyıl Osmanlı Astronomu Takiyüddīn'in Gözlem Araçları: Âlat-ı Rasadiyye li Zîc-i Şehinşâhiyye*, Türkiye İş Bankası Kültür Yayınları, İstanbul 2010, pp. 42-44 and pp. 63-64.

AN OBSERVATION INSTRUMENT INVENTED BY TAQIYADDĪN FOR THE ISTANBUL OBSERVATORY:

07 ĀLĀ MUŠABBAHA BI-L-MANĀṬIQ

Ālāt al-raṣadīya li-zīğ-i Šahinšāhīya written by the Ottoman historian and shahnameh author Seyyid Lokman in Turkish describes nine observation instruments used in the Istanbul Observatory with miniatures.[26] A study of the text describing the instruments reveals that the seventh, eighth and ninth instruments were invented by Taqīyaddīn.

The work specifically underlines that the eighth instrument called Ālā mušabbaha bi-l-manāṭiq had never been constructed before. It is reported that Taqiyaddīn built this instrument for the particular purpose of examining the planet Venus and measuring the radius of its epicycle by drawing upon chapter ten of Ptolemy's *Almagest*.[27]

Our model was built according to the description and drawings in the work.[28]

26 The Ottoman edition and simplified text of this work was first published by Prof. Sevim Tekeli. See: Sevim Tekeli, "Âlât-i Rasadiye li Zic-i Şehinşahiye", *İslâm Tetkikleri Enstitüsü Dergisi*, 1959-1960, Vol. 3 (1-2), pp. 1-30. More recently, the work was published by Prof. Mustafa Kaçar, M. Şinasi Acar and Prof. Atilla Bir, together with the facsimile of three copies, transliteration of the text and its translation into modern Turkish. See: Mustafa Kaçar, M. Şinasi Acar & Atilla Bir, XVI. *Yüzyıl Osmanlı Astronomu Takiyüddīn'in Gözlem Araçları: Âlat-ı Rasadiyye li Zîc-i Şehinşâhiyye*, Türkiye İş Bankası Kültür Yayınları, Istanbul 2010. An autograph copy of the work, which was previously unknown and kept in a private collection was displayed in the exhibition "Nur: Light in Art and Science in the Islamic World" with an inaccurate description. A catalog of the exhibition has been published under the same title: Sabiha Khemir, *Nur: Light in Art and Science in the Islamic World*, Focus-Abengoa Foundation, Seville 2014.

27 See: *Kaçar, Acar & Bir, Takiyüddīn'in Gözlem Araçları ...,* in modern Turkish + technical explanation pp. 44-47, transliteration p. 64, facsimile pp. 78-79, pp. 109-110 [The beginning of the 5th instrument on page 114 is mistakenly reprinted on page 110.], pp. 139-140, 169.

28 Sezgin, *İslam'da Bilim ve Teknik*, p. 61.

THE OLDEST ASTROLABE WITH A KNOWN CONSTRUCTION DATE:

08 NASṬŪLUS ASTROLABE

Although it is not known when the astrolabe, which is one of the most characteristic instruments of Islamic astronomy, was invented, it is estimated that the mathematical projection technique used in the production of the astrolabe was invented in the late ancient world and probably by Hipparchos (2nd Century BC). The word Astrolabe is a combination of two Greek words "Astron" and "Lambanein" and means "star catcher". The word "Astrolabon" in Greek works took the form of "astrolabe" after it was imported by the Islamic world.

The astrolabe is an analog computer that shows the movement (altitude and direction) of the sun in the sky during the day, and some chosen bright stars during the night for any given. Thus, it becomes possible to determine the time and to find the direction by measuring the altitude of the sun or any of the stars on the star pointers, and beyond this, among others, to figure out the time of prayer by finding out the time of sunrise or sunset, or how many degrees below the horizon the sun will be, based on this information. It is estimated that more than a thousand astrolabes have survived until the present day.

There are very few astrolabes that have survived from a thousand years ago. The most common feature of these astrolabes, which are about 12 in number, is that they have a simple and plain appearance in terms of decoration.

Among these early astrolabes, the oldest astrolabe with a known date is a planispheric astrolabe made by an astronomer / instrument master named Nasṭūlus. This astrolabe, which has an important place in the history of science as it is the oldest known astrolabe, is on display in the Dar al Athar al Islamiyyah Museum in Kuwait.[29]

There is no information about the life of Nasṭūlus in classical Islamic sources save for a few sentences.[30] According to the limited information in the sources, his name is Muḥammad ibn Muḥammad or Muḥammad Ibn Abdallāh but he is known as "Nasṭūlus". According to the same sources, Nasṭūlus invented two new non-standard astrolabe types: "moon" and "crab".[31]

Apart from this astrolabe, two astrolabes and an interesting time-measuring instrument by Nasṭūlus have survived to this day.[32] A study of the surviving works reveals that Nasṭūlus was a successful mathematician, astronomer and a good craftsman.

Our model was built based on the original in the museum.[33]

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29 David A. King, "The Earliest Astrolabes from Iraq and Iran", *In Synchrony with the Heavens, Vol 2: Instruments of Mass Calculation*, Part XIII, Vol. 31, pp. 473-476.

30 For information on Nasṭūlus see: David A. King, "A Note on the Astrolabist Nasṭūlus / Basṭūlus", *Archives Internationales d'Histoire des Sciences*, 28 (1978), pp. 117–120; David A. King and Paul Kunitzsch, "Nasṭūlus the Astrolabist Once Again", *Archives Internationales d'Histoire des Sciences*, 33 (1983), pp. 342–343; Francis Maddison and Alain Brieux. "Basṭūlus or Nasṭūlus? A Note on the Name of an Early Islamic Astrolabist ", *Archives Internationales d'Histoire des Sciences*, 24 (1974), pp. 157–160.

31 Fuat Sezgin, *Geschichte des arabischen Schrifttums*, Vol. 6, Leiden 1978, pp. 178-179.

32 David A. King, "Two Newly-discovered astrolabes from 'Abbasid Baghdad", *Suhayl*, Vol. 11, 2012; *Catalogue of the Sotheby's Auction "Arts of the Islamic World",* 11 Oct. 2006, Description of Lot 87. David A. King, "An Instrument of Mass Calculation made by Nastulus in Baghdad ca. 900 ", *Suhayl* 8 (2008): p. 93–119.

33 Sezgin, *İslam'da Bilim ve Teknik*, p. 86.

AN ASTROLABE MADE FOR AN ABBASID PRINCE :

09 AḤMAD B. ḪALAF'S ASTROLABE

This astrolabe, dated approximately to 925, was crafted by Aḥmad b. Ḫalaf, a student of ʿAlī ibn ʿĪsā, one of the early astrolabe makers.[34] It is among the oldest astrolabes that have survived to our day. The Kufic inscription on the astrolabe, "made by Aḥmad b. Ḫalaf for Ǧaʿfar, the son of al-Muktafī", suggests that it was made for Ǧaʿfar b.(ʿAlī) al-Muktafī (d. 987) the son of the Abbasid Caliph al-Muktafī (d. 295/908).[35] The original is preserved in the National Library of Paris with the number GE A 324. This astrolabe is striking in its simplicity and triangular shaped star pointers, which are characteristic of the astrolabes of the Abbasid period.[36]

In Islamic sources, Ǧaʿfar b.(ʿAlī) al-Muktafi is represented as an 'amateur' mathematician and astronomer. In his work titled *Ikhbar al-*ʿUlamā' *bi Akhbār al-Hukamā',* Ibn al-Qifṭī quotes from the book of someone named Ḫars al-Naʿma Muhammed b. Al-Ra'is Hilāl b. El-Muhassin:

"*I have read the following in* Ǧaʿfar *b.*(ʿAlī) al-*Muktafi's autograph copy: "In 225, during the caliphate of Mu'taṣim, a black spot appeared near the center of the Sun. This incident took place on the 19th day of the month of Rajab in 225 (25 May, 840). Two days after this date, that is, after the 21th day of Rajab, events (disasters) occurred. Al-Kindī has mentioned that this spot remained on the Sun for 91 days, and then al-Mu'taṣim died. Before the death of al-Mu'taṣim and al-Rashīd, two comets appeared, as some others had in the past. Al-Kindī said that this spot was due to the Sun being blocked by Venus and both staying in the same position throughout this period. Up until this point, this (information) was taken from the treatise of Ibn al-Muktafi.*"[37]

34 This astrolabe has been studied and published in detail by Silke Ackerman and Taha Yasin Arslan. See: Anthony Turner, Silke Ackermann & Taha Yasin Arslan, *Mathematical Instruments in the Collections of the Bibliothèque Nationale de France*, BNF Éditions / Brepols, London / Turnhout 2018, pp. 27-33. For a previous review by David A. King, see: King, *In Synchrony with the Heavens*, Vol. 2: Instruments of Mass Calculation, s. 466.

35 R. T. Gunther, *The Astrolabes of the World*, p. 230, Nr. 99, Mayer, *Islamic Astrolabists*, p. 37, Ibn an-Nadīm, *al-Fihrist*, p. 904; King, *In Synchrony with the Heavens*, p. 419.

36 For high resolution images of the astrolabe, see: https://gallica.bnf.fr/ark:/12148/btv1b525049523

37 B. R. Goldstein, "Some Medieval Reports of Venus and Mercury Transits", *Centaurus* 14 (1), 1969.

From this quote, it is understood that Ǧaʿfar b.(ʿAlī) al-Muktafī dealt with works on astronomy and collected observation data and that these works were used by other authors. Another author citing Ibn al-Muktafī is Ibn an-Nadīm, the famous bibliographer and book merchant who lived in the 10th century. In one of his quotations from al-Muktafī in the *Al-Fihrist,* Ibn an-Nadīm says:

A Story Relayed from Ibn al-Muktafi's Autograph Copy

*He says: "I read as follows in a book written in Ibn al-*Ǧ*ahm's autograph copy: I gave Sind b.* ʿ*Alī*'s *Kitāb al-Madḫal to Abū Maʿshar al-Balkhī. He compared it with himself. Because Abū Maʿshar learned astrology at an advanced age. Abū Maʿshar's intellect could not capture the knowledge in this book. It is also the same for Tis'u Maq*ālat *fi'l-Mawālīd and Kitāb al-Qiranāt, which is attributed to İbn al-Bāzyār. All of it belongs to Sind b.* ʿAlī."[38]

There is also a work of mathematics dedicated to Ibn al-Muktafī.[39] In light of all this information, it is not surprising that this astrolabe was made for Ibn al-Muktafī.

38 al-Fihrist, p. 882, For other quotations from Ibn al-Muktafi, see. al-Fihrist, p. 62, p. 890 (about astronomer al-Battānī)

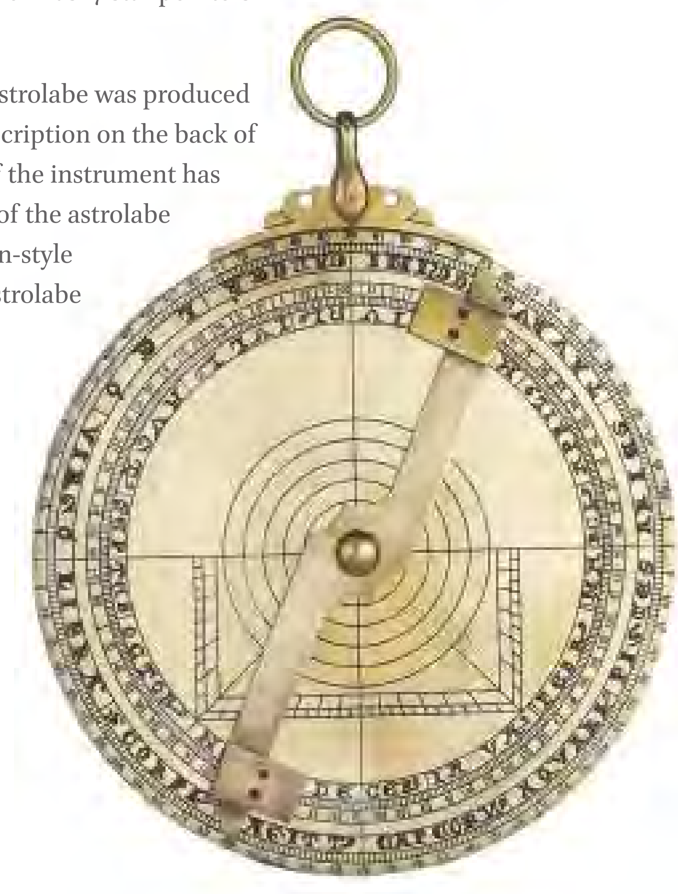
39 Heinrich Suter, *Die Mathematiker und Astronomen der Araber und ihre Werke*, Teubner, Leipzig 1900, p. 64 (142).

10 AN ISLAMIC ASTROLABE ATTRIBUTED TO

POPE SYLVESTER II

This astrolabe, which is in the collection of the world famous Galileo Museum in Florence, Italy, is an early Abbasid astrolabe and its maker is unknown. The front side of the astrolabe is typical Abbasid: An umm (mater) and ‘ankabut (spider), free of ornamentation and decoration. On the ‘ankabut, there is a curved rectangle that follows the equatorial circle on the plate, bearing the triangular star pointers and the star pointers at the bottom of the ‘ankabut. There are two latitude discs on both sides of this astrolabe, which has 17 star pointers on its ‘ankabut.[40]

Although it has been claimed that the astrolabe was produced for Pope Sylvester II due to the Latin inscription on the back of the astrolabe, a detailed examination of the instrument has revealed that the drawings on the back of the astrolabe were added later, inspired by Andalusian-style astrolabes, and the attribution of this astrolabe to Pope Sylvester was not correct.[41]



40 This astrolabe has been studied and published in detail by David A. King. See: King, *In Synchrony with the Heavens*, Volume 2, pp. 489-494. For an older study, see: Gunther, *The Astrolabes of the World*, p. 230 (Nr. 101). See also: Sezgin, *İslam'da Bilim ve Teknik*, p. 94.

41 King, *In Synchrony with the Heavens*, pp. 493-494.

11 THE ASTROLABE OF AL-ḪUĞANDI

THE FAMOUS ISLAMIC ASTRONOMER

Undoubtedly, the most sophisticated and beautiful astrolabe among the surviving astrolabes constructed before 1000 AD, is a planispheric astrolabe built by the Islamic astronomer and mathematician Abū Maḥmūd Ḥamīd B. Al-Ḥidr Al-Ḫuğandī (2nd half of the 4th / 10th century) in 374 AH (986/87 AD).[42]

The original instrument, which is one of the greatest of the early astrolabes, both functionally and artistically, is now displayed at the Museum of Islamic Art in Doha, Qatar. It boasts many additional functions normally not seen in astrolabes due to the fact that it was made by a mathematician / astronomer. There are two panther figures on the throne of the astrolabe and its artistically exquisite ‘ankabut features some star pointers in the shape of a bird.

This astrolabe has influenced other astrolabe makers as well; an astrolabe manufactured by “Badr, associate of the wonder of age, Hibatallāh al-Asturlābī” in 525 AH (1130/31 AD) is very similar to the astrolabe of Ḫuğandi.[43]

Our model was built based on the original in the museum.[44]

42 Detailed analysis of this astrolabe was made by Prof. David King. See: David A. King, “The Earliest Astrolabes from Iraq and Iran”, *In Synchrony of Heavens, Volume 2: Instruments of Mass Calculation*, pp. 445-544, and especially pp. 503-517.

43 This astrolabe is in the Adler Planetarium Museum collection in Chicago. For detailed information see: David Pingree, *Eastern Astrolabes*, Adler Planetarium and Astronomy Museum, Chicago 2009, pp. 38-41. See also: King, *In Synchrony of Heavens, Volume 2: Instruments of Mass Calculation*, pp. 34, 54, 504-12.

44 Sezgin, *İslam’da Bilim ve Teknik*, p. 90.

THE ANDALUSIAN ASTROLABE MASTER

12 MUḤAMMAD IBN AṢ-ṢAFFĀR'S ASTROLABE

Unfortunately, there is not much information about the maker of this astrolabe, Muḥammad İbn eṣ-Ṣaffār. In the fourth chapter of his *Tabaqāt al-*'Umam on the history of the sciences, the Andalusian scholar, the qaḍī of Toledo and astronomer Ṣā'id al-Andalusī (1029-1070) mentions Abu'l'Qāsim Aḥmad b. Abdallāh b. 'Umar (d.1035), the older brother of Muḥammad Ibn aṣ-Ṣaffār and writes: *"He had a brother named Muḥammad who was famous for his mastery in making astrolabes. There has never been a better astrolabe maker in Andalusia"*.[45]

He gives the following information about his brother: *"He was a knowledgeable scholar in arithmetic, geometry and astronomy. He was in Cordoba to teach these sciences. He has a concise zīj on the Sindhind method, succint, articulate, and accessible, and a work titled Al-*'Amal *bi-l-Asturlāb. He left Cordoba shortly after the Abū* 'Āmir *disaster (fitnah). He settled in the city of Denia in the east coast of Andalusia, which was the seat of* Muğāhid ibn al-'Āmirī, *and died there. He educated talented students in Cordoba.*

We will talk about them."[46]

Muḥammad Ibn aṣ-Ṣaffār has two astrolabes known to have survived until today. One of them is in the collection of the Berlin State Library and the other is in the collection of the Museum of Scotland in Edinburgh, Scotland.[47]

The Berlin astrolabe was manufactured in 420 AH / 1029-30 AD; It consists of a mater, 'ankabut, alidade and 9 latitude discs.[48]

45 Ṣā'id al-Andalusī , *Tabaqāt al-*'Umam, Yazma Eserler Kurumu, Istanbul 2014, p. 180.

46 al-Andalusī , *Tabaqāt al-*'Umam, p. 182.

47 For detailed analyses of Ibn aṣ-Ṣaffār's astrolabes, see: Azucena Hernández Pérez, *Catálogo Razonado de Los Astrolabios de La España Medieval*, Ediciones de La Ergástula, Madrid 2018. For images and information on the Royal Museum's website, see: https://www.nms.ac.uk/explore-our-collections/collection-search-results/astrolabe/216943

48 Azucena Hernández Pérez, *Catálogo Razonado de Los Astrolabios de La España Medieval*, Ediciones de La Ergástula, Madrid 2018, pp. 51-58.

13

THE ASTROLABE BY AḤMAD B. MUḤAMMAD AN-NAQQĀṢ

THE ANDALUSIAN ASTROLABE MASTER

Crafted by Aḥmad b. Muḥammad an-Naqqāṣ in Saraqusta (present day Saragossa) in 472 AH (1079-80 AD), this astrolabe is approximately 11.5 cm in diameter and has 5 latitude discs in addition to the mater, ʻankabut and alidade. Unfortunately, the sources offer no information about its maker.[49] The striking aspect of the astrolabe in terms of decoration is the pattern on the spider in the form of segmented arches just like the astrolabe of Ibrāhīm b. Sāʻid as-Sahlī. The form of the decoration is reminiscent of the segmented arches that were used extensively in the al-Ğaʻfariyah (Aljaferia) palace built by the Banū Hūd family in the city of Saragossa in the same period.[50]

The city of Saragossa was an important scientific center in Andalusia at the time this astrolabe was made. According to various sources, the family of Banū Hūd, who ruled in this city, and especially Aḥmad al-Muqtadir bi-Llāh (1049-1081) and his son Mū'taman ibn Hūd were known as scholars in many subjects. Mū'taman ibn Hūd, who ascended the throne exactly one year after this astrolabe was made, ruled between 1081 and 1085. Known as a versatile scholar and an excellent mathematician according to historical sources, ibn Hūd wrote a work titled *Istikmal* (literally "complete, perfect").[51] The Ceva theorem attributed to the Italian mathematician Giovanno Ceva (1647-1734), was actually presented by Mū'taman ibn Hūd.[52] Moreover, research on the works referenced or quoted in *Istikmāl* has revealed that this family had an extremely rich library.[53] Following the Christian overtake of Saragossa in 1118, this library was first moved to Rueda de Jalón; subsequently, the last member of this dynasty Aḥmad III Abū Ğaʻfar Sayf al-Dawla moved all his property, including his library, to Toledo in 1140.[54]

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49 For detailed information about this astrolabe, see: Hernández Pérez, *Catálogo Razonado*, pp. 103-110; Mayer, *Islamic Astrolabists*, p. 37. Fuat Sezgin, *İslam'da Bilim ve Teknik*, p. 96

50 Hernandez Pérez, *Catálogo Razonado*, p. 122.

51 or general information in Turkish, see: Mehmet Özdemir, "Hûdîler", DİA, Türkiye Diyanet Vakfı Yayınları, Istanbul 2007, Vol. 18, pp. 301-302. For detailed information about Mū'taman ibn Hūd and his work *Istikmal*, see: Jan P. Hogendijk, Discovery of an 11th-Century Geometrical Compilation: The Istikmal of Yusuf al-Mu 'taman ibn Hud, King of Saragossa, *Historia Mathematica 13* (1986), pp. 43-52; Hogendijk, Al-Mu'taman ibn Hud, 11th Century King of Saragossa and Brilliant Mathematician, *Historia Mathematica* 22 (1995), 1-18; Hogendijk, The Geometrical Parts of the Istikmal of Yusuf al-Mu'taman Ibn Hud (11th Century): An analytical table of contents, *Archives Internationales d'Histoire des Sciences* (1991), Vol. 41; Hogendijk, Which version of Menelaus' Spherics was used by al-Mu'taman ibn Hud in his Istikmal? in: Menso Folkerts (ed.), *Mathematische Probleme im Mittelalter - der lateininsche und arabische Sprachbereich*, Harrassowitz Verlag, Wiesbaden, 1996, pp. 17-44.

52 Audun Holme, *Geometry: Our Cultural Heritage*, Springer Verlag, Berlin -Heidenberg 2010, pp. 193-194.

53 Charles Burnett, "Translations, Scientific, Philosophical, and Literary (Arabic)" in: E. Michael Gerli, *Medieval Iberia: An Ecyclopedia*, Routledge, New York 2003; Dag Nikolaus Hasse, "The Social Condition of the Arabic- (Hebrew-) Latin Translation Movements in Medieval Spain and in the Renaissance", in: A. Speer and L. Wegener, eds., *Wissen über Grenzen. Arabisches und lateinisches Mittelalter*, de Gruyter, Berlin 2006, pp. 22–31.

54 Charles Burnett, The Coherence of the Arabic-Latin Translation Program in Toledo in the Twelfth Century, *Science in Context* 12 (1/2), 2001, pp. 249-288.

About ten years later, in 1150, Toledo became the center of translations from Arabic into Latin.[55] Perhaps the most interesting fact that has emerged from research is that some of the translations made in the scope of this movement known as the 12th century Renaissance, were made from works in the Banū Hūd Library.

Taken together, it can be argued that this astrolabe represents not only an Andalusian city, but also a rich scientific tradition that has left a deep imprint in Europe.

55 Burnett, *Arabic-Latin Translation Program*, pp. 249-288.

el-Caferiye (Aljaferia) sarayı, Zaragosa, İspanya

14 THE ASTROLABE BY IBRĀHĪM B. SĀʿID AS-SAHLĪ

THE ANDALUSIAN ASTROLABE MASTER

The Andalusian astrolabe master Ibrāhīm b. Sāʿid as-Sahlī lived and worked in the cities of Toledo and Valencia.[56] Only five of the astrolabes he made have survived to the present day.[57] Apart from that, he is the producer of one of the two Andalusian celestial globes that have survived until today.[58] This celestial globe, which he crafted with his son in the city of Valencia on 1 Safar 478/29 May 1085 for a ruler by the name Abu Isa b. Lubbūn, is in the collection of the Galileo Science History Museum in the city of Florence today.[59]

The astrolabe in question was made by as-Sahlī in Valencia in 478 AH (1086 AD).[60] Apart from the mater, ʿankabut and alidade, the astrolabe has 9 latitude discs.

This astrolabe by Ibrāhīm b. Sāʿid as-Sahlī is remarkable with its ornaments in the form of a segmented arch or mihrab on its spider where each segment is in the shape of an arch. These decorations are reminiscent of the segmented arches that were used extensively in the al-Jaʿfariyah (Aljaferia) palace built and used in the city of Saragossa in the same period.[61]

The astrolabe is currently preserved in the Museumslandschaft Hessen Kassel (MHK) Museum in Kassel, Germany.[62]

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56 Hernández Pérez, *Catálogo Razonado,* p. 121; Gunther, *Astrolabes of the World*, p. 263; Mayer, Islamic Astrolabists, pp. 51-52; Fuat Sezgin, *İslam'da Bilim ve Teknik*, p. 97. For the history and development of astrolabes in Andalusian civilization, see: Hernández Pérez, *Astrolabios en al-Andalus y Los Reinos Medievales Hispanos*, Ediciones de La Ergástula, Madrid 2018.

57 Julio Samsó, *On Both Sides of the Strait of Gibraltar: Studies in the History of Medieval Astronomy in the Iberian Peninsula and the Maghrib*, Brill, Leiden 2020, p. 328. For detailed analyses of these astrolabes, see: Hernandez Pérez, *Catálogo Razonado*, no. A6, A7, A8, A12 and A13.

58 For detailed information about this celestial globe, see: Emilie Savage-Smith, *Islamicate Celestial Globes: Their History, Construction and Use*, Smithsonian Institution Press, Washington D.C. 1985, pp. 24, 214, 217, 236.

59 For images of the globe on the museum website, see: https://catalogue.museogalileo.it/object/CelestialGlobe_n14.html

60 Hernandez Pérez, *Catálogo Razonado*, pp. 121-130.

61 Hernandez Pérez, *Catálogo Razonado*, pp. 122.

62 For the information in the database on the museum site, see: http://datenbank.museum-kassel.de/34401/

15 THE ASTROLABE BY MUḤAMMAD B. FUTŪḤ AL-ḪAMĀʼIRĪ

THE ANDALUSIAN ASTROLABE MASTER

At least 14 astrolabes by al-Ḫamāʼirī, one of the leading astrolabe masters of Islamic Andalusia, have survived to the present day.[63] Two of these astrolabes are in collections in Turkey; one is in the collection of the Turkish-Islamic Arts Museum and the other is in the collection of Istanbul Technical University.[64]

The astrolabe in the Istanbul Technical University collection has features that distinguish it from others. First of all, one of the latitude discs inside the astrolabe was made for the latitude of Paris, 48 ° 22 ‘. Moreover, modern numerals were engraved on the spider of the astrolabe instead of the original abjad numerals (writing the numbers in Arabic letters), while the original Arabic inscriptions on the rim of the mater (cell) were erased and replaced by Latin names and symbols.

This astrolabe's history in Turkey is also interesting. This astrolabe is known to have been donated by Sultan Selim III to the Imperial School of Military Engineering that was the predecessor of Istanbul Technical University along with some other instruments and books.[65] Page 22 of the work titled *Riyād al-Muhtār mirʼat al-miqyās wa-l-advār maʻa maǧmūʻāt al-aškāl* by the Ottoman Grand Vizier Gazi Ahmed Muhtar Pasha on the topic of astronomical instruments, calendars and latitude / longitude determination has detailed drawings of this astrolabe.[66] At the top of the page, there is the statement "*True size picture of an astrolabe in the library of the Imperial School of Military Engineering in Dersaadet"*.[67]

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63 Nine astrolabes by al-Ḫamāʼiri were examined and described in detail in the Medieval Spanish Astrolabes Catalog published in 2018 by the Spanish historian of science Azucena Hernández Pérez. Unfortunately, the two astrolabes by al-Ḫamāʼiri in Turkey are not included in this book. See: Hernández Pérez, *Catálogo razonado de los astrolabios de la España medieval, Ediciones* De La Ergastula, Madrid 2018.

64 Unfortunately, these two astrolabes have not been studied in detail yet. For information and images about the astrolabe in the Turkish Islamic Arts Museum, see: http://islamicart.museumwnf.org/database_item.php?id=object;ISL;tr;Mus01;25;en

65 Celal Kolay, "Prof. Dr. Kazım Çeçen'in İTÜ'de "Bilim ve Teknoloji Tarihi Müzesi" Kurma Çalışmaları", *İTÜ Vakfi Dergisi*, September-December (2019), no. 84. pp. 42-44.

66 Gazi Ahmet Muhtar Pasha, *Riyād al-Muhtār mirʼat al-miqyās wa-l-advār maʻa maǧmūʻāt al-aškāl,* Bulak Publishing House, Cairo 1303/1306. For detailed information about Gazi Ahmet Muhtar Pasha, see: Rifat Uçarol, "Gazi Ahmed Muhtar Paşa", DİA, Türkiye Diyanet Vakfı Yayınları, Istanbul 2007, Vol. 13, pp. 447-448.

67 Some letters in the original text are printed incorrectly.


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16 THE ASTROLABE MADE BY AL-MALIK AL-AŠRAF

The Rasulid Dynasty, which ruled in Yemen between 1231 and 1454, had many members who were scientists. Some of the works written by the members of the dynasty covering a wide range of subjects such as astronomy, medicine, agriculture and linguistics have survived to the present day.[68]

An astrolabe personally made by Al-Malik al-Ašraf, the second member of the dynasty, is now on display in the Islamic Art section of the Metropolitan Museum in New York.[69]

It is interesting that the work written by Al-Malik al-Ašraf on the making of astrolabes has survived to the present day and is preserved at the Egyptian National Library in Cairo at number TR 105. The astrolabe drawing in this manuscript is almost identical to the drawings on the astrolabe in the Metropolitan Museum. The inclusion of two ijazahs (permissions to teach) given by the astronomy teacher of the sultan in the manuscript in Cairo makes this copy a rare document for the history of science. As far as is known, this manuscript is the only copy that includes the treatise by a sultan describing the production of the astrolabe he himself built and the ijazahs.[70]

The astrolabe in our exhibition was made as a reproduction of the original instrument in the Metropolitan Museum.[71]

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68 For the Rasulid dynasty and its scientific activities and works, see: Cengiz Tomar, "Resûlîler", *DİA*, Vol. 35, p. 1-2; Peter Golden, T. Halasi-Kun, Thomas T. Allsen, *The king's dictionary: the Rasulid Hexaglot-fourteenth century vocabularies in Arabic, Persian, Turkic, Greek, Armenian, and Mongol*, Brill, Boston & Leiden 2000; Daniel M. Varisco, ibn Y. 'Umar, *Medieval Agriculture and Islamic Science: The Almanac of a Yemeni Sultan*, Seattle: University of Washington Press, 1994; Malik al-Afḍal, Daniel M. Varisco, Gerald R. Smith, *The Manuscript of Al-Malik Al-Afḍal Al-*'Abbās *B.* 'Alī *B. Dā'ūd B. Yūsuf B.* 'Umar *B.* 'Alī *Ibn Rasūl:* (*d. 778/1377*)*; a Medieval Arabic Anthology from the Yemen*, Warminster Gibb Memorial Trust, 1998.

69 A detailed analysis of this astrolabe was made by Prof. David A. King. See: King, *In Synchrony with the Heavens*, pp. 619-646.

70 Information on manuscripts and ijazahs in Cairo is offered in the reference given in footnote 69.

71 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 2 p. 105.

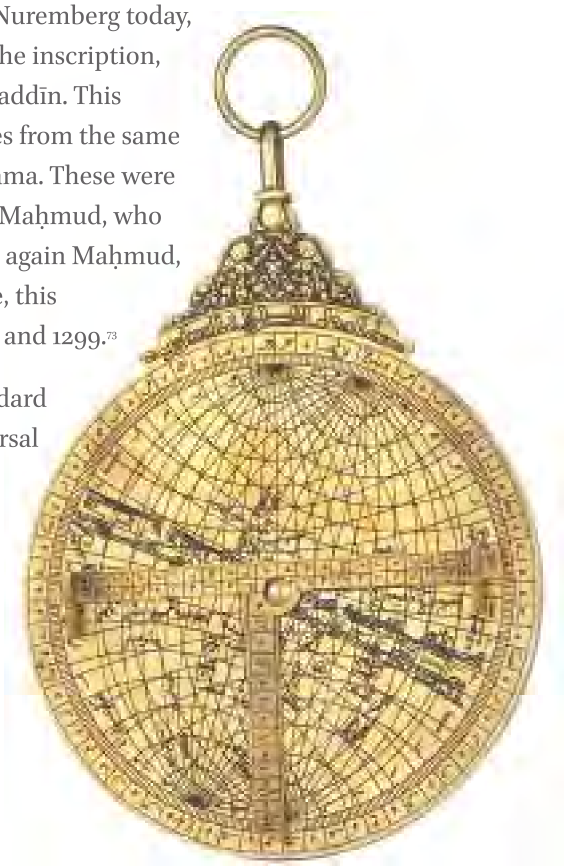
ONE OF THE MOST ARTISTIC ASTROLABES:

17 AL-SAHL AL-NISABURI'S ASTROLABE

Astrolabes, which arrived in the Islamic civilization as very simple and plain instruments, were perfected both functionally and artistically by undergoing a great change within the Islamic civilization. Over time, these astrolabes, which were decorated with the basic elements of Islamic art such as calligraphy, geometric decoration and flower motifs, constituted the best examples of how science and art have merged in Islamic civilization.

Astrolabes with animal or human figures are rare. The most exquisite of these limited numbers of astrolabes is probably the astrolabe crafted by al-Sahl al-Nisaburi in the 12th or 13th century.[72]

Preserved at the Germanisches National Museum in Nuremberg today, this astrolabe was built for a ruler who, according to the inscription, bears the title of al-Malik al-Muẓaffar Maḥmud Taqīyaddīn. This ruler must have been one of the three Ayyubid princes from the same family and known by the same name who ruled in Hama. These were Umar, who ruled after 574 AH [1178/79], his grandson Maḥmud, who ruled between 626 [1228/29] and 642 or his grandson, again Maḥmud, who ruled from 683 [1284/85] to 698 [1299]. Therefore, this undated astrolabe must have been built between 1178 and 1299.[73]



Although the front face of the astrolabe is of the standard planispheric astrolabe type, the back side has a universal type Sakkāzīya projection. This instrument, which travelled from Syria to Italy in the late Middle Ages, eventually landed in the Nuremberg City Library and was given to the museum in 1877.[74]

Our model was built based on the original in the museum.[75]

72 For a detailed analysis of this astrolabe, see: King, *In Synchrony with the Heavens: Vol 2*, Part XIVb, pp. 677-684. For information about and images of the astrolabe on the official website of the museum, see: http://objektkatalog.gnm.de/objekt/WI20.

73 King, *In Synchrony with the Heavens*, p. 680.

74 King, *In Synchrony with the Heavens*, p. 677.

75 Sezgin, *İslam'da Bilim ve Teknik*, p. 104.

18

AN ASTROLABE MADE FOR AN OTTOMAN SULTAN:

THE ASTROLABE OF SULTAN BAYEZID II

Only two astrolabes made for an Ottoman sultan have survived to this day. One of them is in the Cairo Museum of Islamic Art and the other is in a private collection. Apart from these two instruments, there are no other extant instruments representing the early Ottoman instrument-making tradition. All other Ottoman astrolabes were manufactured at least one century after Sultan Bayezid II's astrolabes.

It is not surprising that both of the earliest Ottoman astrolabes that have survived until today were built for Sultan Bayezid II. Sultan Bayezid II's interest in astronomy is well-known.[76] Sultan Bayezid II took astronomy lessons from Mirim Çelebi, the grandson of Qādī-Zadeh Rūmī. Moreover, a considerable number of astronomical works were dedicated to Sultan Bayezid II.[77]

This model astrolabe, whose reproduction is available here, was manufactured by an astrolabe master named Muḫlīṣ Shirwānī in 910 AH (1504/05 AD) and is preserved in the Museum of Islamic Art in Cairo today.

Our model is based on the original in the museum.[78]

76 Ahmet Tunç Şen, "Reading the Stars at the Ottoman Court: Bāyezīd ii (r. 886 / 1481-918 / 1512) and His Celestial Interests ", *Arabica, Vol.* 64 (2017), no.: 3-4.

77 David A. King, "Two Astrolabes for the Ottoman Sultan Bayezit II", *In Synchrony with the Heavens*, pp. 781-796, especially pp. 784-792.

78 Sezgin, *İslam'da Bilim ve Teknik*, p. 109.

19 ZARQĀLĪ'S UNIVERSAL ASTROLABE

The major disadvantage of standard planispheric astrolabes, is that they require a separate disc for each latitude. This problem was largely solved by universal astrolabes produced using a different stereographic projection technique invented by Andalusian astronomers in the 11th century.

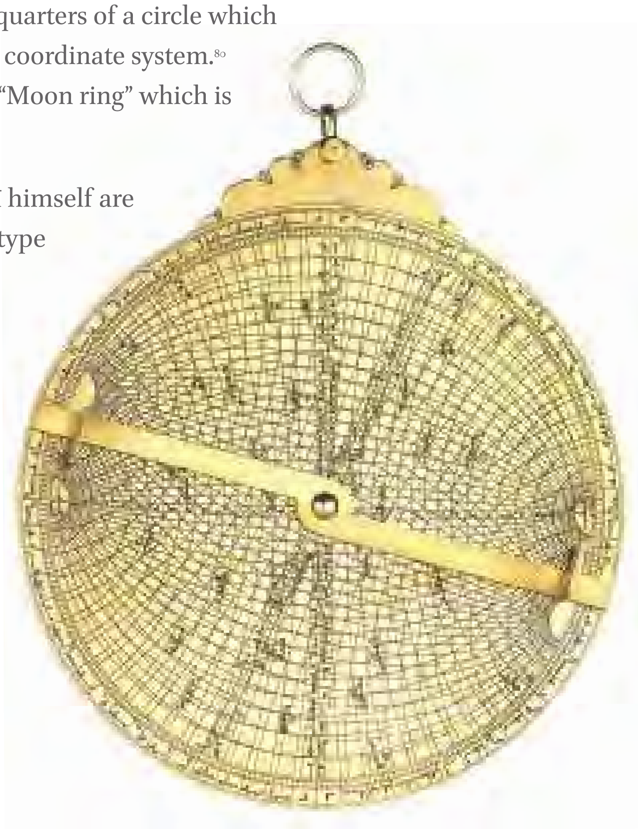
Ibrāhīm b. Yaḥyā az-Zarqālī who was one of these astronomers (2nd half of the 11th century) developed two different types of universal astrolabes: as-Ṣafīḥa Sakkāzīya and as-Ṣafīḥa Zarqālīya.[79]

Consisting of a single disc, the front of this astrolabe includes equatorial and ecliptic coordinate spiders placed on top of one another following the angle of the ecliptic tilt. A Zarqālīya disc resembles two Sakkāzīya disks positioned on top of each other at a certain angle.

On the back, there is a spider covering three-quarters of a circle which is the orthogonal projection of the equatorial coordinate system.[80] Also, there is a simple but clever invention, a "Moon ring" which is used to find distances to the Moon.[81]

Although the astrolabes crafted by az-Zarqālī himself are no longer extant, astrolabes of the Zarqālīya type exist today.

Our model was commissioned by Prof. Fuat Sezgin and is the reproduction of an astrolabe built by one of Andalusia's most famous astrolabe producers Muḥammad b. Futūḥ al-Ḫamā'irī, in possession of the Rome Observatory.[82]



79 For a list of Sakkāzīya or Zarqālīya astrolabes that survived until today, see: http://www.davidaking.org/instrument- catalog-TOC.htm.

80 For detailed information about this spider, see: Roser Puig, "La proyección ortográfica en el Libro de la Açafeha alonsi", *De Astronomia Alphonsi Regis*, Barcelona 1987, pp. 125-138.

81 For detailed information about the Moon ring, see: Roser Puig, "al-Zarqlluh's graphical method for finding lunar distances", *Centaurus*, 32 (1989), pp. 294-309.

82 Sezgin, *İslam'da Bilim ve Teknik*, p. 117.

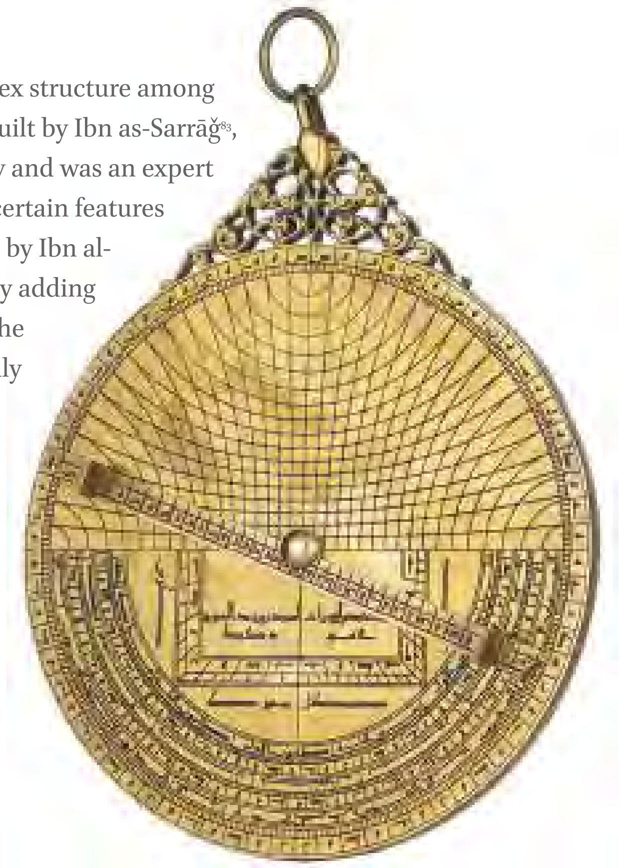
THE MOST SOPHISTICATED MEDIEVAL ASTROLABE:

20 THE UNIVERSAL ASTROLABE OF IBN AS-SARRĀĞ

Apart from the standard planispheric astrolabe, which was the most common type of astrolabe in the Medieval period, Islamic astronomers have developed many new and more sophisticated astrolabes. Some of these astrolabe types classified as non-standard, are called universal astrolabes. Unlike standard or planispheric astrolabes, the astrolabe does not require using different latitude discs for different latitudes and can be used in all latitudes, hence the term "universal".

The universal astrolabe, which has the most complex structure among the astrolabes that have survived until today, was built by Ibn as-Sarrāǧ[83], who lived in the Mamluk period in the 14th century and was an expert on astronomical instruments.[84] Ibn as-Sarrāǧ used certain features of the universal astrolabe developed and described by Ibn al-Ḫalaf and produced a highly developed astrolabe by adding new functions to it. This astrolabe is on display in the Benaki Museum in Athens today. Unfortunately, only a Castilian translation remains from Ibn al-Ḫalaf's universal astrolabe.[85] According to the world-renown Islamic astronomical instruments expert Prof. David King, "Ibn as-Sarrāǧ's astrolabe is the most sophisticated astrolabe of the whole Middle Ages and the Renaissance".[86]

Our model is based on the original in the museum.[87]



83 For his life see François Charette, *Mathematical instrumentation in fourteenth-century Egypt and Syria: The illustrated treatise of Najm al-Dīn al-Mīṣrī,* Leiden, Brill 2003, pp. 16-17.

84 King, *In Synchrony with the Heavens*, pp. 694-700.

85 Charette, *Mathematical instrumentation*, pp. 105-106.

86 Charette, *Mathematical instrumentation*, p. 16.

87 Sezgin, *İslam'da Bilim ve Teknik*, p. 119.

THE OLDEST WESTERN ASTROLABE IN EUROPE:

21 THE CAROLINGIAN ASTROLABE

The oldest astrolabe that has survived to the present day and that was made in the West is called the "Carolingian Astrolabe". This astrolabe was purchased in 1961 by Marcel Destombes, an officer and astronomical instrument collector in the French naval forces, and its authenticity was the subject of extensive debate after it was published in an article by Destombes.[88] An international symposium was held about this instrument in Saragossa in Spain, bringing together expert paleographers, historians of medieval astronomy, and metallurgists who also supported Destombes's earlier claim about the instrument's authenticity and that it belonged to an earlier period.[89] This instrument, which is one of the most important documents about the influence of the Islamic world on Europe, has been described as a 10th century Carolingian-era Catalan astrolabe by experts who have studied it.[90]

This astrolabe has some unusual features. First of all, there are no inscriptions on the front of the astrolabe. There are only inscriptions on the 'ankabut's ecliptic circle, which were added at a later point in time. There are also 20 star pointers, but only 18 of them correspond to a real star. These starts are yet to be identified. Although the latitude discs inside the astrolabe correspond to the Greek astronomer Ptolemy's descriptions of "climate", one is different and its two sides correspond to the latitude of two different cities, Rome and Barcelona.[91] Furthermore, there is the inscription "ROMA ET FRANCIA" on the face of the disc according to the latitude of 41; 30 °.[92]

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88 Julio Samsó, *On Both Sides*, s. 392-397; In David A. King, "The earliest European astrolabe in the light of other early astrolabes", in: Wesley Stevens, Guy Beaujouan & Anthony J. Turner, eds., *The Oldest Latin Astrolabe*, Physis - Rivista di storia della scienza, Novel 1996, pp. 359-404.

89 Samsó, *On Both Sides*, p. 396.

90 Samsó, *On Both Sides*, p. 396.

91 Samsó, *On Both Sides*, p. 393.

92 Samsó, *On Both Sides*, p. 394.


SCORPIO
LIBRA

Since the word Francia in this article cannot have anything to do with France, it remained a question mark for a long time and it was finally concluded that this word was a translation of the word *Ifranja*, which is used as a geographical term denoting the Christian kingdoms in the northeast of the Iberian peninsula in the 10th-12th century Arab sources.[93]

Julio Samsó, the Spanish historian of Islamic science, has argued that this astrolabe is a copy of an Andalusian astrolabe, possibly produced based on the translation of an Islamic astrolabe presented as a gift on the occasion of a diplomatic visit to Barcelona by the Jewish vizier Hasdai ibn Shaprut sent by the Umayyad Caliph Abd al-Raḥmān III, or by a mission sent by the Count of Barcelona to Cordoba.[94] Samsó has even suggested that the craftsman who copied the Arabic original was probably a novice as he had to draw several of the circles on the astrolabe twice.[95] According to Samsó, the craftsman who built the astrolabe was assisted by someone who could read and interpret an Islamic astrolabe. The most interesting element that corroborates this claim is that some numbers on the astrolabe are written in Latin letters indicating the abjad numerals widely used in Islamic astrolabes instead of Roman numerals (A = Alif = 1, B = Ba = 2, C =Ğim , = 3, D = Dal = 4.).[96]

93 Samsó, *On Both Sides*, p. 396.

94 Samsó, *On Both Sides*, p. 396.

95 Samsó, *On Both Sides*, p. 396.

96 Samsó, *On Both Sides*, p. 396.


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22 THE LUPITUS MANUSCRIPT ASTROLABE

This astrolabe is not a reproduction of a real astrolabe but was inspired by an interesting drawing in an astrolabe treatise found in a Latin manuscript copied in a monastery 1000 years ago. Preserved in the Burgersbibliothek Library in Bern, Switzerland, and dated to approximately 1000, this manuscript contains a treatise entitled *Sententiae astrolabii* by an author known as Lupitus of Barcelona.[97]

This work is partly translation and partly adaptation of an astrolabe treatise by the famous 9th century mathematician and astronomer Muḥammad ibn Mūsā al-Khwārizmī, consisting of three parts: 1) Introduction, 2) Description of the astrolabe and its parts, 3) The use of the astrolabe. Having compared the Latin text with the Arabic text by al-Khwārizmī, Paul Kunitzsch states that only one-seventh of the work is a direct translation and that the author added many explanatory sentences.[98]

The most striking point in the drawings in the manuscript is that the four drawings depicting the parts of the astrolabe in the manuscript contain either Arabic alphabetic numerals or their transliterations using Latin letters. For example, the drawing depicting the latitude disk of the astrolabe features the inscriptions "vaev, iebe, ieha, kefdal, lam, lamvaev" next to the altitude rings. These inscriptions are numbers written in abjad numerals that clearly go up in sixes, which are widely used in İslamic astrolabes (waw = 6, ya + ba = 12, ya + ha = 18, kaf + dal = 24, lam = 30, lam + waw = 36).

This manuscript and the work in it provide clues as to how this scientific transmission was adopted in the 10th and 11th centuries, when the heritage of Islamic science was just beginning to enter Europe.[99]

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97 http://katalog.burgerbib.ch/detail.aspx?ID=129280. For a review of the astrolabe treatise in this work, see: Matthias Schramm, Carl-Philipp Albert and Michael Schütz, Martin Brunold, ‚Das Astrolabtext aus der Handschrift Codex 196, Burgerbibliothek Bern', *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* 17, pp. 199-300.

98 Paul Kunitzsch, Al-Khwarizmi? As a source for the for the Sententie Astrolabi, in: Annals of the New York Academy of the Sciences, 500. Number 1. *From Deferent to Equant: From Deferent to Equant: A Volume of Studies in the History of Science in the Ancient and Medieval Near East in Honor of E.S. Kennedy,* pp. 227-236.

99 For an interesting study on the methods by which this transfer and adoption occurred in the context of Astrolabes, see: Arianna Borelli, *Aspects of the Astrolabe: 'architectonica ratio' in tenth- and eleventh-century Europe*, Franz-Steiner, Stuttgart 2008.

THE ONLY SPHERICAL ASTROLABE THAT HAS REMAINED INTACT UNTIL OUR DAY:

23 THE OXFORD ASTROLABE

Shortly after the planispheric astrolabe, which is referred to as the "standard astrolabe" in the literature, was transmitted from the ancient world to Islamic civilization, the development of astronomical instruments in Islamic civilization gained great momentum and Islamic scholars started to invent different types of astrolabes in addition to the planispheric astrolabe.[100] One of these so-called non-standard astrolabes is the "spherical astrolabe". The inventor of the spherical astrolabes invented in the 9th century was probably Ḥabaš al-Ḥāsib, one of the foremost astronomers and mathematicians of the period. Even though it is not certain that he is their inventor[101], the fact that he wrote one of the first treatises on spherical astrolabes makes him important. Apart from Ḥabaš al-Ḥāsib, Qusṭā bin Lūqā and an-Nairīzī in the 9th century and al-Wāsiṭī in the 10th century wrote treatises on the spherical astrolabe.[102] In the 11th century, we come across a description about the making of a spherical astrolabe in al-Bīrūnī 's encyclopedic work on astrolabes titled *Isti'āb al-Wuǧūh al-Mumkina*.

Nearly all of the section on the use and construction of spherical astrolabes in *Libros del Saber de Astronomia*, which was prepared by the order of the Wise King Alfonso X in the 13th century through the translation of many Arabic treatises into Castilian, was based on Islamic sources.[103]

Only two spherical astrolabes have survived to our day, and only one of them is complete. This astrolabe in the Oxford Science History Museum, which is 8.3 centimeters in diameter and 261.7 grams in weight, was made by a man named Musa in 885 AH /1480-81 AD.[104]

Our model is based on the original in the museum.[105]

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100 For detailed information about spherical astrolabes, see: Sezgin, *İslam'da Bilim ve Teknik*, pp. 120-122; Charette, *Mathematical Instrumentation*, pp. 61-62; David A. King, *Spherical Astrolabes in Circulation: From Baghdad to Toledo and to Tunis & Istanbul*, 24 November 2018 version.

101 King, *Spherical Astrolabes,* p. 14.

102 For the analysis of an-Nairīzī's treatise and the German translation of its introduction, see: Seeman & Mittelberger, " *Das Kugelförmige Astrolab nach den Mitteilungen von Alfons X von Kastilien un der vorhandenen arabischen Quellen* ", *Erlangen*, 1925 (Abhandlungen zur Geschichte der Naturwissenschaften der Medizin. Heft VIII) For a reprint see: *Islamic Mathematics and Astronomy* series, Vol. 88, Frankfurt 1988, pp. 359-431. For Arabic texts of an-Nairīzī and al-Wāsiṭi and their Italian translations and commentaries, see: Ornella Marra, *L'astrolabio sferico e il suo uso. Il Kitāb fī l-'amal bi'l-asturlāb al-kurī attribuito ad al-Nayrīzī*, Luciano Editore, 2002.

103 Julio Samsó, "Alfonso X", *Biographical Encyclopedia of Astronomers*, (ed. Thomas Hockey), Springer Reference 2007, pp. 29-30.

104 Prof. David A.King, who has carried out a detailed analysis of the astrolabe suggests that the astrolabe was built by the Jewish scholar Mūsā Jalīnūs (Moshe Galeano) who lived in Istanbul in the 15th century.

105 Sezgin, *İslam'da Bilim ve Teknik*, p. 131.

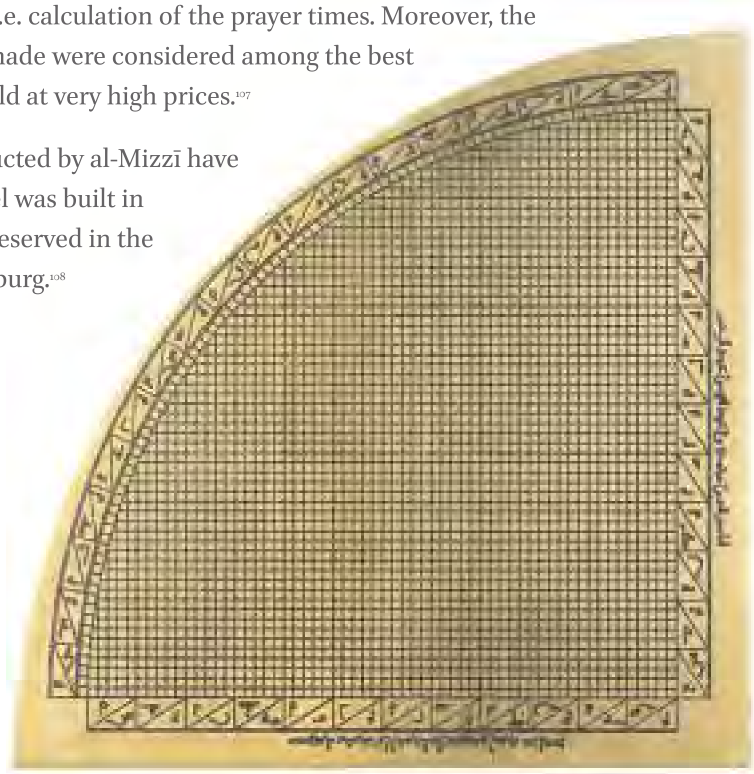
FAMOUS MUWAQQIT AND ASTRONOMICAL INSTRUMENTS MASTER

24 AL-MIZZĪ'S QUADRANT

A muwaqqit (mosque astronomer) and an astronomical instrument master, Muḥammad b. Aḥmad al-Mizzī, who also wrote many treatises on astronomical instruments, was born in the village of Mizze, probably near Damascus in 1291 AD. Sources about his life state that he studied in Egypt and that he was tutored by the famous Egyptian physician and encyclopedist Ibn al-Akfānī.[106]

Working at the Umayyad Mosque in Damascus as a muwaqqit until his death, al-Mizzī owed his reputation to the fact that his didactic treatises were very popular among students who studied the science of miqāt, i.e. calculation of the prayer times. Moreover, the astrolabes and quadrants he made were considered among the best quality of its time and were sold at very high prices.[107]

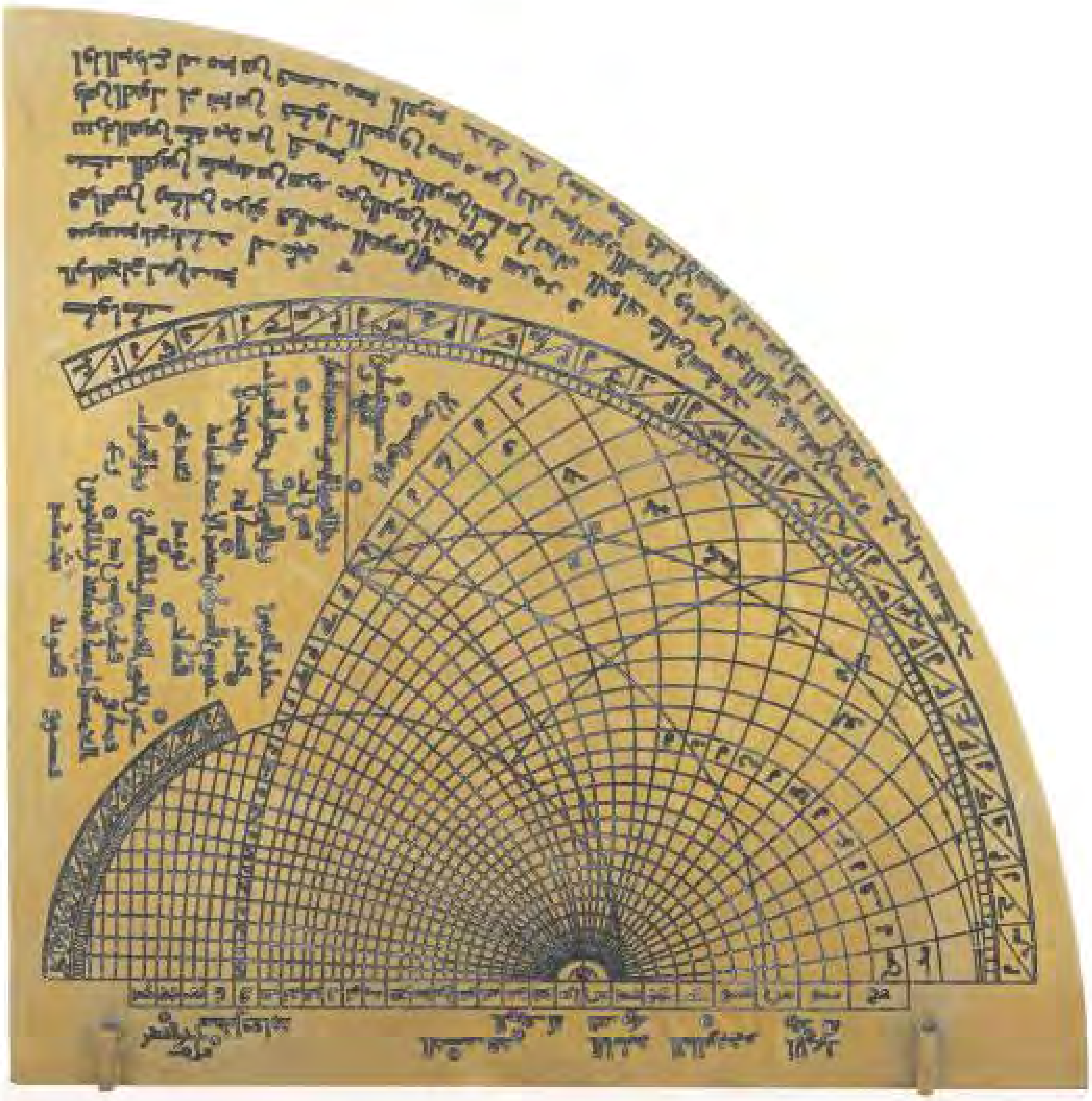
At least five quadrants constructed by al-Mizzī have survived to this day. Our model was built in accordance with the model preserved in the Oriental Institute in St. Petersburg.[108]



106 Thomas Hockey et al. (eds.), *The Biographical Encyclopedia of Astronomers*, Springer Reference, New York: Springer 2007, pp. 792-793.

107 Charette, *Mathematical Instrumentation*, pp. 13-14.

108 Sezgin, *İslam'da Bilim ve Teknik*, p. 136.



25 ABŪ ǦAʿFAR EL-ḪĀZIN'S EQUATORIUM

The term equatorium, which is derived from the Latin word Aequatio, i.e. equation (meaning: correction), is essentially a tool to find the longitude degrees of the Sun, Moon and planets in the ecliptic "visually / geometrically". Undoubtedly, the greatest advantage provided by such an instrument is to find these degrees with as little calculation as possible unlike the method of determination by calculation. The famous mathematician Abū Ǧaʿfar Muḥammad b. al-Husain al-Ḫāzin, who was active during the second half of 4th / 10th century, developed an instrument that he called Zīj aṣ- Ṣafā'īḥ and gave the same title to the work he wrote about this instrument.[109]

After a series of studies, researchers concluded that this instrument was an early equatorium. Unfortunately, only a single instrument of this type has survived to our day and it is incomplete. The front face of the main disc is designed as a standard astrolabe, and a zīj (astronomical table) is engraved on the back surface of the instrument which can be used as an equatorium.[110]

An incomplete copy of al-Ḫāzin's *Zīj aṣ- Ṣafā'īh,* the book that was assumed to be missing until recently, was found by chance in the Srinagar Research Library in Kashmir. It was therefore possible to reproduce the missing parts of the instrument that survived until today.[111]

Our model was built according to the description and drawings in the work.[112]

109 Sezgin, *İslam'da Bilim ve Teknik*, pp. 177-179.

110 Sezgin, *İslam'da Bilim ve Teknik*, pp. 177-179.

111 David A. King, "New Light on the Zīj al-Ṣafā'īh of Abū Jafar al-Khāzin", *Centaurus* 23, 1980, p. 105-117.

112 Sezgin, *İslam'da Bilim ve Teknik*, pp. 177-180

ANDALUSIAN ASTRONOMER

26 AZ-ZARQĀLĪ'S EQUATORIUM

In Andalusia, the first equatorium independent of the Oriental Islamic world was probably developed by Ibn as-Samḥ (d.1035) who was known as Abulcasim in Europe. Subsequently, az-Zarqālī (d.1100) followed suit with a more sophisticated equatorium. Finally, Abu ṣ-Ṣalt (around 1067-1034) developed a model of an equatorium. Although the equatorium, developed by Ibn as-Samḥ, consisted of different plates, each representing a separate planet, placed in a main disc like the astrolabe, the instruments by az-Zarqālī and Abu ṣ-Ṣalt are composed of a single disc.

Az-Zarqālī wrote two works on this instrument that he called Ṣafīḥa az-Zīǧīya. Of these two works, only the one related to the use of the instrument has survived and was partially prepared as a critical edition by José Millás Vallicrosa and published in Spanish.[113]

Our model was built according to the description and drawings in the work.[114]

113 Sezgin, *İslam'da Bilim ve Teknik*, p. 183; José Millás Vallicrosa, *Estudios sobre Azarquiel*, Madrid-Granada, 1943-1950, pp. 458-483.

114 Sezgin, *İslam'da Bilim ve Teknik,* p. 183.

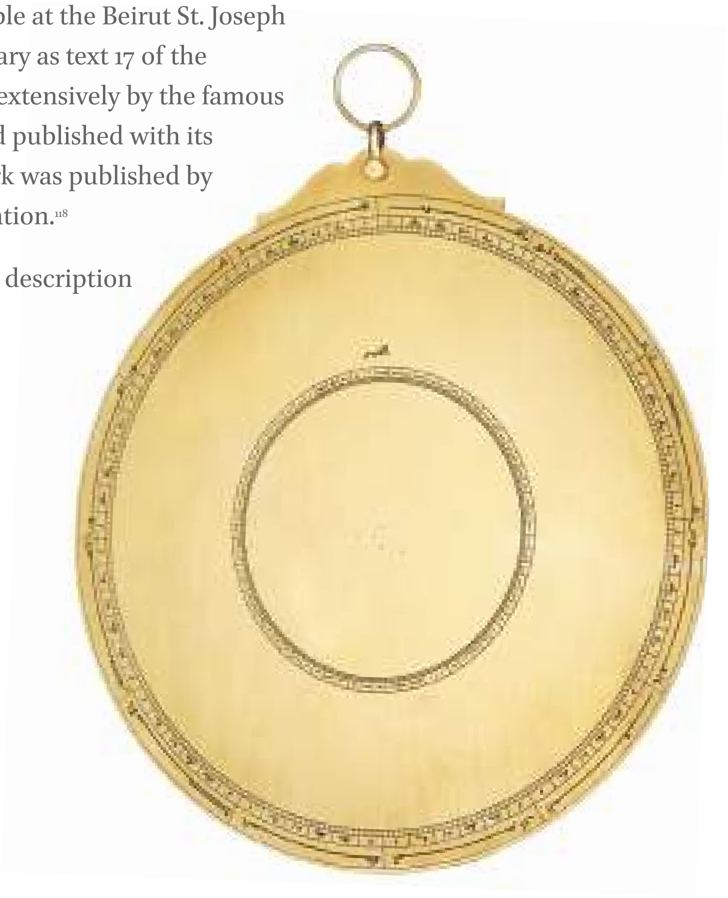
AN ANDALUSIAN POLYMATH

27 ABU Ṣ-ṢALT'S EQUATORIUM

An Andalusian scholar, Umaiya b. ʿAbdalʿaziz b. Abu ṣ-Ṣalt al-Andalusī (460-529 / 1068-1135) wrote works on history, literature, music, philosophy, medicine and astronomy.[115] His works generated a great deal of interest in Europe and were translated into Hebrew and Latin. According to some Arab sources, Abu ṣ-Ṣalt was a very good lute player and was instrumental in the development of māluf style music by bringing Andalusian music to Tunisia. In his work on astronomy titled *Ṣifat* ʿAmal *Ṣafīḥa Ǧāmi*ʿa *Taqawwama bi-hā Ǧamīʿ al-Kawākib al-Sabʿa* (Description of the Universal Plate on which the Totality of the Seven Planets are Gathered), he described an equatorium which he designed himself, similar to az-Zarqāli's equatorium.[116]

This work, which is currently accessible at the Beirut St. Joseph University Oriental Manuscripts Library as text 17 of the manuscript no. 223, was first studied extensively by the famous historian of science E.S. Kennedy, and published with its drawings.[117] The Arabic text of the work was published by Mercè Comes with its Spanish translation.[118]

Our model was built according to the description and drawings in the work.[119]



115 Hockey, *The Biographical Encyclopedia of Astronomers*, pp. 9-10.

116 Hockey, *The Biographical Encyclopedia of Astronomers*, pp. 9-10.

117 E. S. Kennedy, "The Equatorium of Abū al-Ṣalt", *Physis* 12, 1970, pp. 73-81.

118 Mèrce Comes, *Ecuatorios Andalusies*, Barcelona 1991, pp. 139-157, 237-251.

119 Sezgin, *İslam'da Bilim ve Teknik*, p. 185.

28

ĞAMŠĪD AL-KĀŠĪ'S

ANALOG ASTRONOMIC COMPUTER

Although the inventor of the equatorium was Abū Ğaʿfar el-Ḫāzin from the Oriental Islamic world, the major development took place in Andalusia. The equatorium, whose different models were developed by Andalusian scholars such as Ibn as-Samh, az-Zarqālī and Abu ṣ-Ṣalt, once again reached its climax in the Oriental Islamic geography with the great mathematician and astronomer Ğamšīd b. Maḥmūd Ġiyātaddīn al-Kāšī (d. 832/1429).

In his *Nuzhat al-ḥadā'iq* (819/1416), which he wrote before starting to work at the Samarkand Observatory, al-Kāšī described the construction and use of two instruments, one of which is equatorium he called *ṭabaq al-manāṭiq*.[120]

Unlike other equatoria, this instrument makes it possible to find not only the longitudes but also the latitudes of the planets at the same time.

Our model was built according to the description and drawings in the work.[121]

120 This work was first examined by the famous science historian E.S. Kennedy. Kennedy published a series of articles studying the two equatoria described in the work. He subsequently published it with its Farsi and English translations, facsimile and technical explanations, whose additional copies are in the Garett Collection at Princeton University Library. See: E. S. Kennedy, *The Planetary Equatorium of Jamshīd Ghīyath al-Dīn al-Kāshī* (d. 1429): An Edition of the Anonymous Persian Manuscript 75 [44b] in the Garett Collection at Princeton University, Princeton Oriental Studies, Volume 18, Princeton University Press, Princeton: New Jersey 1960.

121 Sezgin, *İslam'da Bilim ve Teknik*, p. 192.

AN ASTRONOMIC CALCULATOR DESIGNED BY EL-KĀŠI: (LAUḤ AL-ITTIṢĀLĀT)

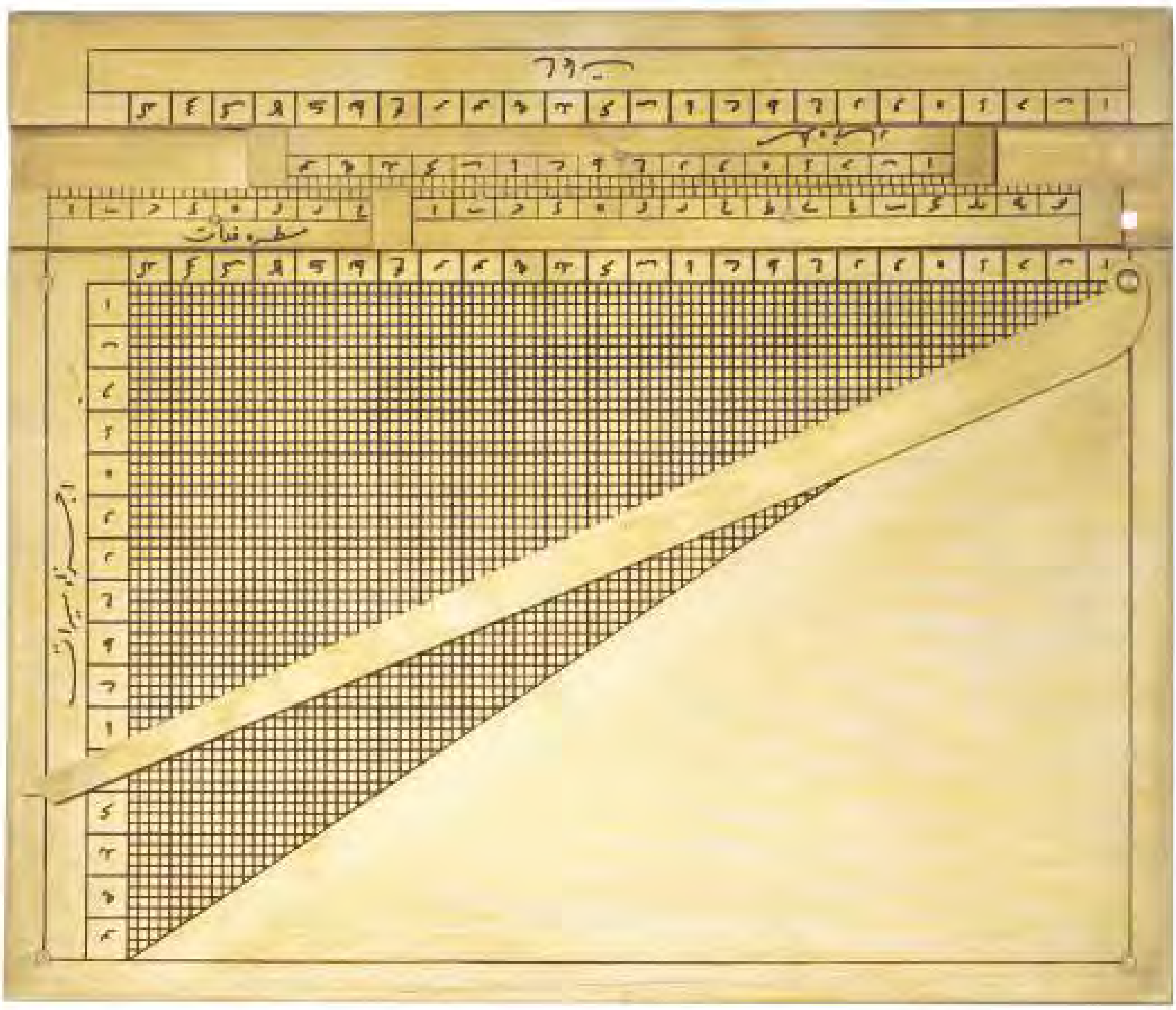
29 CONJUNCTION CALCULATOR

Another instrument Ǧamšīd b. Maḥmūd al-Kāšī (d. 832/1429) describes in his *Nuzhat al-ḥadā'iq* (819/1416) is Lauḥ al-ittiṣālāt (table of conjunctions), which makes it easy to calculate the approaches and conjunctions of the planets in the zodiac belt.[122] This plate, which functions like an analog computer, enables the user to determine the exact time when the conjunction between two approaching planets will take place based on their known position and approach speeds at noon by applying the interpolation method "graphically".

Our model was built according to the description and drawings in the work.[123]

122 Kennedy, "The Planetary Equatorium", pp. 68-79 (facsimile + English translation) and pp. 241-243 (technical description).

123 Sezgin, *İslam'da Bilim ve Teknik*, pp. 196-197.



AL-BĪRŪNĪ'S

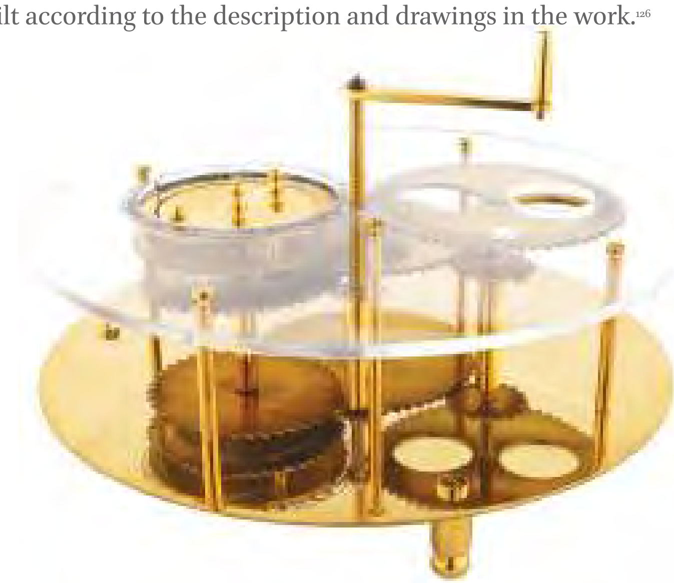
30 MECHANICAL LUNAR CALENDAR

One of the leading names in the history of Islamic science, Muḥammad b.Aḥmad al-Bīrūnī (d. 440/1048) produced original works in many fields such as the history of religions, pharmacy, astronomy, mathematics, physics, geology and geodesy. His *Kitāb fī Istīʿāb al-wuǧūh al-mumkina fī ṣanʿat al-asṭurlāb,* an encyclopedic work on the astrolabe, became very popular in the Islamic world. In this work, al-Birūnī describes many different types of astrolabes invented by astronomers in Islamic civilization, accompanied by figures. At the end of the work, there is a description of a mechanical-astronomical lunar calendar with a gear mechanism.[124]

This mechanism, called the "Moon Box" (Ḥuqq al-qamar), makes it possible to learn the position and phase of the Moon for any date (by entering the ecliptic longitude of the Sun) thanks to a gear set inside it.

In this work, al-Birūnī states that different masters prefer different gear sets and that all these different gear sets are an approximate solution. As is understood from al-Bīrūnī's argument, this instrument is not his own invention and was already widely known in his era. The fact that a portable sundial and mechanical calendar from the Roman period, whose fragments are currently in the Science Museum of London, is similar to the instrument described by al-Birūnī demonstrates that the tradition of these instruments dates back to the late antiquity.[125]

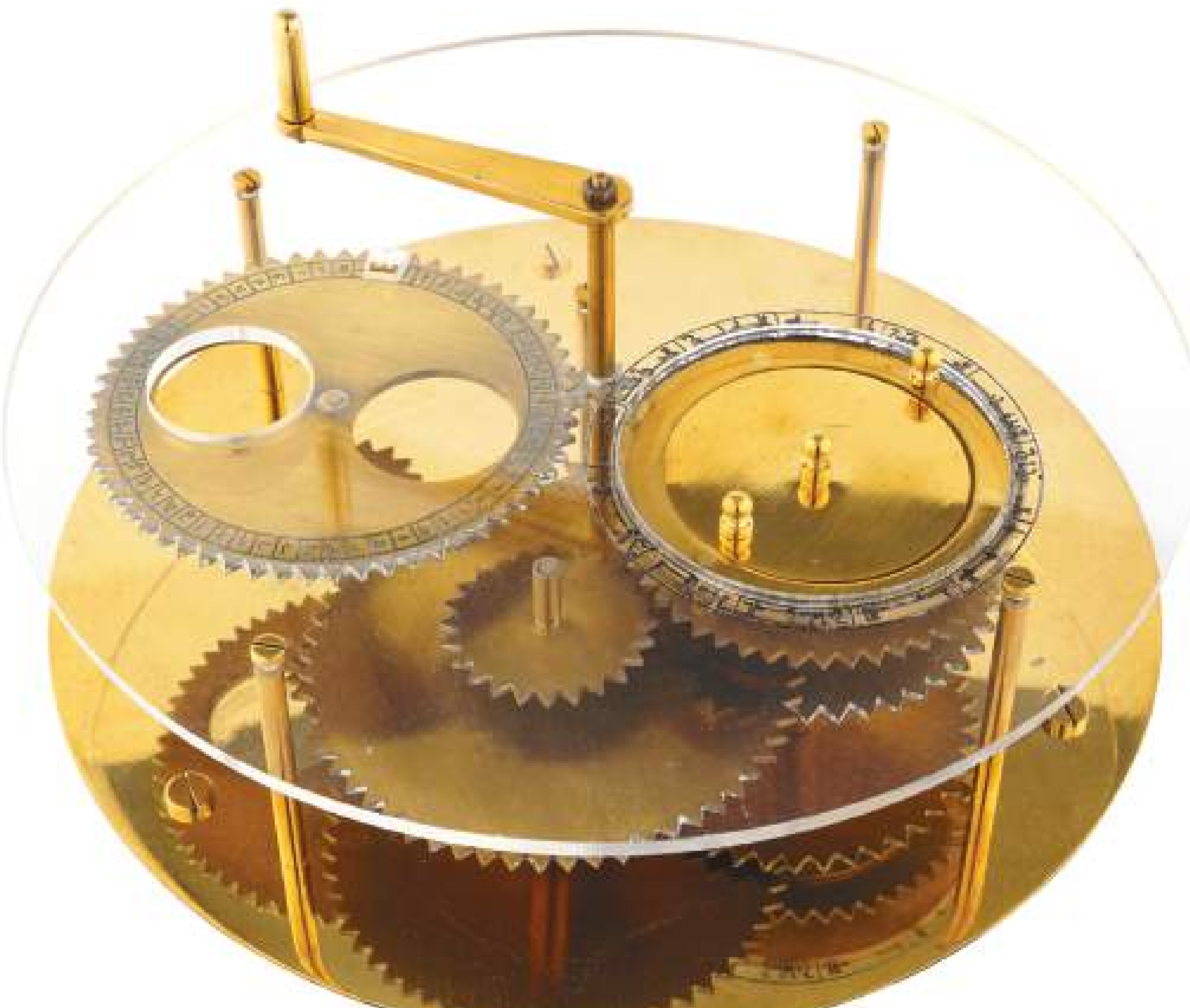
Our model was built according to the description and drawings in the work.[126]



124 Al-Birūnī's mechanical lunar calendar was first studied by the German orientalist and historian of science Eilhard Wiedemann, then revisited by Donald R. Hill and published with an Arabic critical edition, English translation and analysis. See: Donald R. Hill, "Al-Biruni's Mechanical Calendar", *Annals of Science*, 42 (1985), pp. 139-63.

125 Richard J. A. Talbert, *Roman Portable Sundials: The Empire in Your Hand*, Oxford University Press, Oxford 2017, pp. 82-87.

126 Sezgin, *İslam'da Bilim ve Teknik*, pp. 164-165.



MUḤAMMAD B. ABĪ BAKR AL-IṢFAHĀNĪ'S

31 MECHANICAL-ASTRONOMICAL CALENDAR

This astrolabe, which was made by Muḥammad b. Abī Bakr al-Iṣfahānī in 618 AH/ 1221/22 AD, includes the oldest fully geared mechanism in the history of Islam.[127] Although the front of the astrolabe is a normal planispheric astrolabe, there is a three-span calendar on the back, one showing the Moon phase, one the numerical age of the Moon, and the other the positions of the Sun and Moon in the zodiac.[128]

The back cover of the astrolabe can be opened. There is a gear calendar mechanism inside the astrolabe. The sign indicating the phase of the Moon is the same as in the mechanical lunar calendar described by al-Bīrūnī in his *Isti'ab.* At the same time, the pointers indicating the positions of the Sun and Moon are designed as symbols made of gold and silver. The cogwheel used in the astrolabe is different from the one described by al-Bīrūnī.[129]

Compared to the one in al-Bīrūnī's mechanism, the cogwheel of this astrolabe appears cleverly simplified. Although the number of wheels with an odd number of teeth in al-Bīrūnī's mechanism is five, this number is only one in al-Iṣfahāni's astrolabe. The significance of this is that the geometrical drawing and production of wheels with an odd number of teeth is much more difficult than those with even numbers.

There is a circular inscription on the edge of the back of the astrolabe. The inscription states :

This is an astrolabic disc, and it can show you a waxing and waning crescent; the bodies of the Sun and Moon in the sky when they are in opposition or conjunction, or their positions in their orbits for a given year, month or for the present time. This disc is the product of the labor of someone educated in the technical arts based on precision and scientific evidence. Look at the disc! It will show you most of the wonders that prove the wisdom of the Merciful; different movements have meanings that materialize thanks to a single Mover and go beyond all meanings.[130]

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127 For detailed information about this astrolabe, see: J. V. Field & M. T. Wright, *Early Gearing: Geared Mechanisms in the Ancient and Medieval World*, Science Museum, London 1985; J. V. Field & M. T. Wright, "Gears from the Byzantines: A Portable Sundial with Calendrical Gearing", *Annals of Science*, 42 (1985), pp. 117-121; Gunthers, *Astrolabes of the World*, pp. 119-20.

128 https://www.hsm.ox.ac.uk/geared-astrolab

129 Field & Wright, Early Gearing, p. 24.

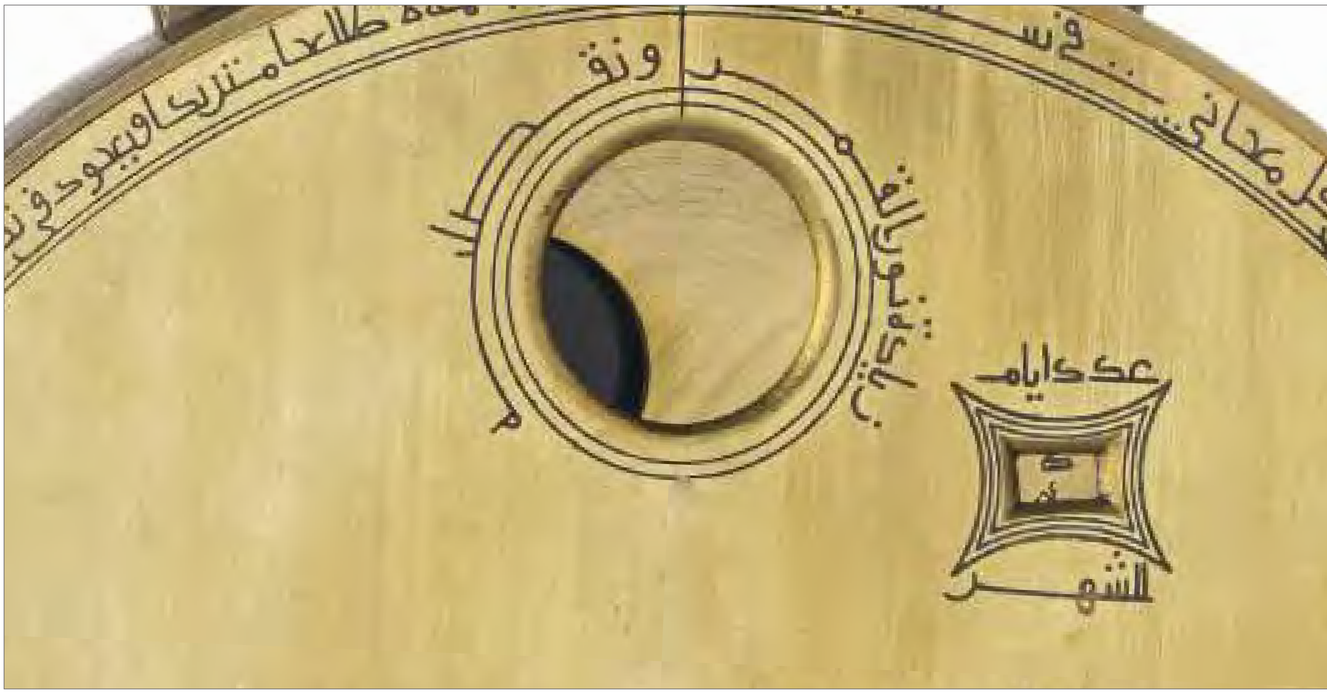
130 The translation on the website of the museum is different from the translation given by Gunther in his work. This translation is based on the translation available in the Oxford Museum online database, with minor changes. See: http://www.mhs.ox.ac.uk/ collections/ imu-search-page / record-details /? TitInventoryNo = 48213 & querytype = field & thumbnails = on & irn = 2217

This astrolabe is very valuable in terms of aesthetics as well as technique. In this context, two elements are particularly striking in the ʿankabut (spider) on the front of the astrolabe. In the upper central part of the ʿankabut, there is a four-leaf foil (quatrefoil) and below it are two semicircles with wings.

These same figures can also be seen in the famous astrolabe of al-Ḫuǧandī dated 986/87. Moreover, three of the star pointers are in the form of animal figures, with one being a horse and two being birds. Moreover, different human figures and zodiac symbols were engraved on the rim of the mater of this relatively thick astrolabe.

In addition to making astrolabes, Muḥammad b. Abī Bakr al-Iṣfahāni is known to have written works on astronomy.[131]

131 Suter, *Die Mathematiker und Astronomen*, p. 139, no. 349.


عدد ايام
الشهر


جرما النيرين يجتمعان
يوم الاجتماع ويتقابلان
يوم الاستقبال

AL-ḪĀZINĪ'S

32 SELF-ROTATING SPHERICAL CLOCK

A scholar educated in the city of Merv, Abu al-Fath ʿAbdarrahmān al-Mansūr al-Ḫāzinī, was a freedman of Abu'l Husayn ʿAlī b. Muḥammad al-Ḫāzin al-Marwazī of Byzantine origin.[132] He is known as "al-Ḫāzinī" due to the fact that his master was a treasurer (ḫāzin) in Merv Palace, and was given a good education by his master.

Known specifically for his studies in astronomy and physics, al-Ḫāzinī invented a rotating celestial and wrote a treatise about it.[133] The two surviving copies of this work are in the Thurston 3 (118r-119r) manuscript in Bodleian Library in Oxford and manuscript 4871 (73r-74r) in Ẓahirīye Library in Damascus.[134]

The cylinder moves downwards under the effect of the slow discharge of sand filled in a cylindrical casing; This clock works by rotating the sphere to which it is connected with a pulley and gear mechanism in 24 hours and shows the situation of the sky from moment to moment.

Our model was built according to the description and drawings in the work.[135]

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132 For general information about al-Ḫāzinī's life and works, see: Robert E. Hall, "al-Khāzinī", *Dictionary of Scientific Biography*, Vol. VII (1973), p. 335-351; J. Vernet, "al-Khazinī", *Encyclopaedia of İslam: Second Edition*, Vol. IV, p. 1186; Sadettin Ökten, "Abdurraman el-Hâzini", *DİA*, Vol. 1, pp. 164-165.

133 This treatise has been studied and published by Richard Lorch, together with its critical edition and English translation. See: Richard Lorch, "Al- Khāzinī's 'Sphere That Rotates by Itself'", *Journal for the History of Arabic Science,* 4 (1980), pp. 287--329.

134 Both journals are very important in terms of the history of science.

135 Sezgin, *İslam'da Bilim ve Teknik*, p. 172.

CONSTRUCTED FOR A MEMLUK GOVERNOR, IBN AṢ-SĀṬIR'S

33 "RUBY CASKET"

The most important astronomer of the 14th century and the chief muwaqqit of the Umayyad Mosque in Damascus, ʿAlī b. Ibrāhīm b. Muḥammad Ibn aṣ-Sāṭir, was best known for his new astronomical instruments and planetary theories.[136]

One of the interesting instruments (767AH/1366AD) invented by Ibn aṣ-Sāṭir for a Mamluk governor in Damascus was the instrument he called the "Ruby Casket".[137] This portable palm-sized instrument called Ṣandūq al-yawāqīṭ al-ǧāmi ʿli- aʿmāl al-mawāqīt (Ruby Casket for All Time Measurements) is now preserved in the Aleppo Awqaf Library.[138] The instrument has two sundials, one polar and the other equatorial. The equatorial sundial is used to find the hour angle of the Sun (and the stars). There is also a compass on the instrument. This instrument is important because it is the oldest Islamic instrument with a compass that has survived to the present day.

Another aspect that makes Ibn aṣ-Sāṭir's instrument important in the history of astronomical instruments is that it was an important step in the development of the instrument known as "Torquetum" in Europe, which started with Ǧābir b. Aflaḥ.[139]

Our model is based on the original.[140]

136 David A. King, "Ibn al-Shāṭir: 'Alā' al-Dīn 'Alī ibn Ibrāhīm'; Thomas Hocker et al (ed.), *The Biographical Encyclopedia of Astronomers*, Springer, New York 2007, pp. 569-570.

137 A detailed analysis of this instrument has been carried out by Prof. David A. King and Louis Janin. See: Louis Janin & David A. King, "Ibn al- Shāṭir's Ṣandūq al-Yawāqīt: An Astronomical 'Compendium'", *Journal for the History of Arabic Science* (1977), Vol 2. No. 1, pp. 187-242.

138 The only surviving piece of another "Ruby Casket" is in the Kandilli Observatory Collection.

139 Sezgin, *İslam'da Bilim ve Teknik*, p. 157.

140 Sezgin, *İslam'da Bilim ve Teknik*, pp. 155, 157.

IBN AL-HAIṮAM’S INSTRUMENT

34 FOR DETERMINING THE MERIDIAN LINE

Establishing the exact direction of the meridian line was one of the fundamental problems in ancient and medieval astronomy as some instruments had to be aligned exactly along this line for accurate measurements.

One of the earliest known methods, called the “Indian Circle”, was to place a vertical pole into the ground and draw a circle around it. The next step was to wait for the shadow to shorten enough to touch the circle. Then a mark would be made on that spot. Then the shadow would get shorter until the Sun reached noon altitude, the shadow would reach its shortest length at the zenith point, and then the shadow would begin to lengthen again as the Sun descended. Another mark would be made at the moment the shadow touched the circle again just before leaving it. When two marks are connected by a straight line, all lines perpendicular to this straight line are meridian lines.

Although this method was very simple, medieval astronomers such as al-Bīrunī and Ibn al-Haiṯam who were good and experienced in mathematical astronomy, knew that a small error occurred because the Sun’s declination changed throughout the year and day.

Both astronomers tried to find more accurate and precise ways to determine the meridian. Ibn al-Haiṯam developed a new instrument that used a fixed star instead of the Sun and measured the equal altitudes of a given star before and after its culmination to determine the meridian line. He described this instrument in detail in his treatise entitled *Āla li- stiḫrāǧ ḫaṭṭ nisf an-nahār.*[141]

141 A critical edition of this treatise was prepared by Prof. Fuat Sezgin and published in Arabic with annotations. See: Fuat Sezgin, “Tarīqat Ibn al-Haytham fī Maʿrifat Ḫaṭṭ Niṣf en-Nehār“, *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften*, Frankfurt, 3/1986, Arabic.

Since the fixed star's declination is independent of the seasons, in theory, the horizontal angle of a star before and after the meridian transit should be exactly the same at equal altitudes, thus resulting in a symmetrical and more accurate observation.

The device consists of an aiming bar mounted on a platform. The platform is mounted on a base by means of a pole that can be rotated to left and right. Ibn al-Haiṯham states in the text stated that the platform should be mounted vertically so the instrument can be used for stars above the horizon. The base is equipped with a circular scale to measure the angle of rotation. The instrument is initially aligned in a simpler and less precise way. Accurately observing two equal altitudes of a star and finding the middle of the two corresponding symmetrical directions will clearly indicate the more accurate direction of the meridian line and the difference from the less accurate previous alignment, if any.

In the West, the 15th century astronomer Regiomontanus is known to be the first to use this method for determining the meridian.[142]

142 Rudolf Wolf, *Handbuch der Astronomie*, ihrer Geschichte und Litteratur. Schulthess, Zürich 1890-1893.

کمیه کورفزی
منغشلاق
قره قلپاق
اراضئ کورکند
نهر کورکند
کات
جند
ایلاق
خیوه
فاراب
حکومت
اراضئ بولسنبك
کیواق
نهر کیواق
هزارسف
قره باش طاغلری
اراضئ اوزبك
بخاری
سمرقند
کیش
نسف
اسفیکند

Geography and Navigation

AL-IDRĪSĪ'S

35 MISSING WORLD MAP

Norman King Roger II, who reigned in Sicily in the 12th century, invited the famous geographer Abū ʿAbdallāh Muḥammad b. Muḥammad aš - Šarīf al-Idrīsī to work in his palace, and al-Idrisī accepted this invitation and entered the service of the king. Al-Idrīsī, who stayed in Sicily from about 1138 to 1161, prepared maps and wrote geographical works at the request of the king.[143] In his introduction to his best known work *Nuzhat al-muštāq fī iḫtirāq al-āfāq*, he relays how the king engaged in the preparation of an up-to-date world map and how he collected the information to write a geography book that would accompany this map.

The king first examined geography books and then consulted geographers. However, he saw that the knowledge of geographers did not go beyond books. When the knowledge he acquired in this process was not enough, he invited scholars with travel experience to his palace as a last resort and consulted them on the subject. He saw that there were differences of opinion among them. He then accepted the information on the issues they agreed on, and rejected the issues on which they disagreed. According to al-Idrīsī, this process took about 15 years. The next step was to combine all this information, and the King had a drawing plate (Lawḥ at-Tarsīm) brought for this exercise and he engraved the information on the plate himself. Finally, King Roger ordered that a world map of 112 dirhams (approximately 134 kg) in weight be made of pure silver, and that "seven climates, countries and regions, gulfs and seas, waterways and rivers, areas with and without life and the distances between places" engraved on this map.[144]

After the silver map was produced, King Roger wanted a book including the information on the map to be written but the book had to have much more information. The king named it *Nuzhat al-muštāq fī iḫtirāq al-āfāq*. Al-Idrīsī completed the work, which contained seventy maps, in the month of Shawwal of 548/1154.[145] Unfortunately, this round silver plate, known as the Tabula Rogeriana, was broken and divided among rebels during a revolt six years after the death of King Roger.

Our model was commissioned by Prof. Fuat Sezgin to create an impression about this missing map.[146]

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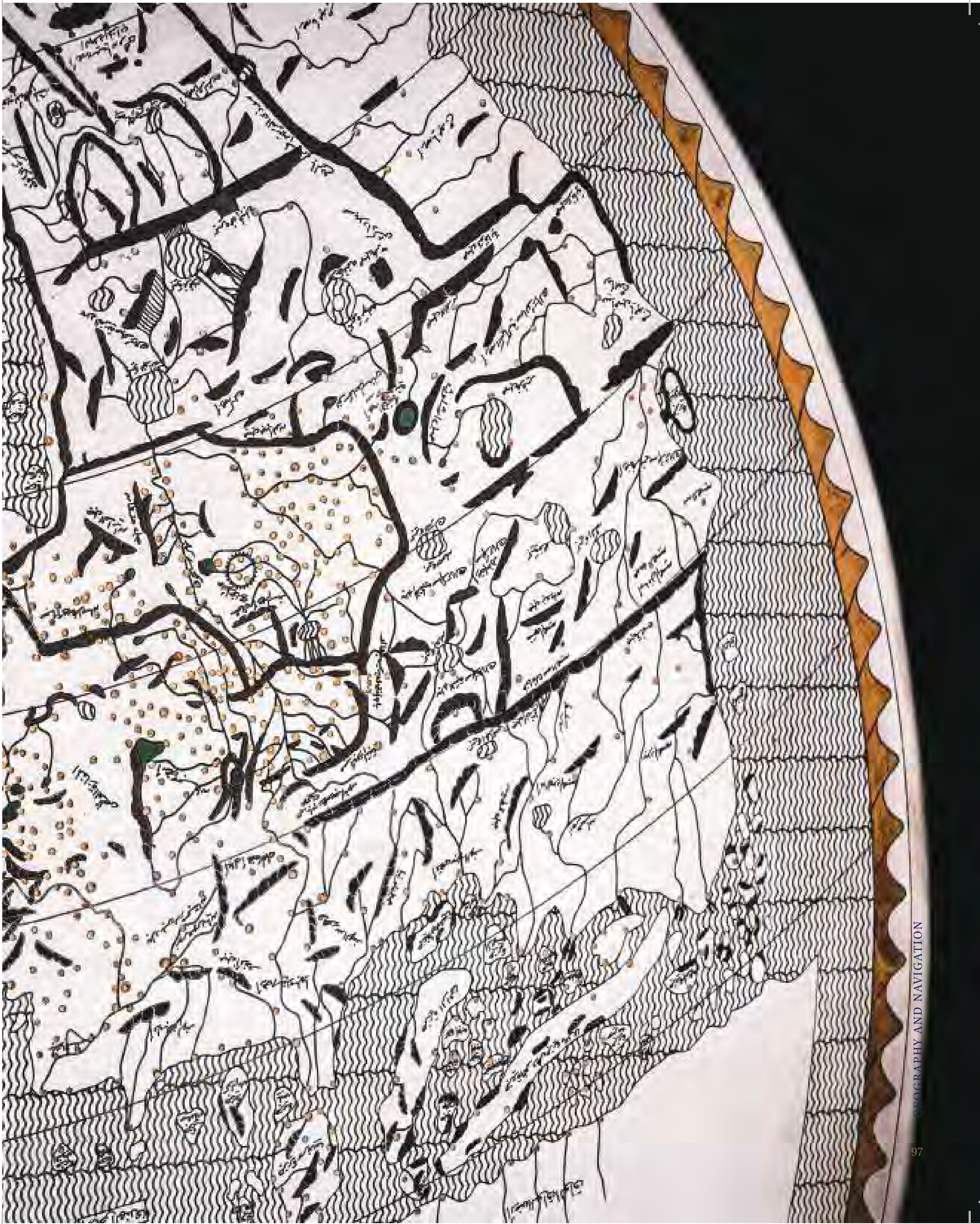
143 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 3, pp. 4-5.

144 S. Maqbul Ahmad, "Cartography of al-Sharif al-Idrīsī", J. B. Harley & David Woodward (ed.), *The History of Cartography,* Vol. 2, University of Chicago Press, 1992.

145 Ahmad, "Cartography of al-Sharif al-Idrīsī", s. 5.

146 Sezgin, *İslam'da Bilim ve Teknik,* Vol. 3, p. 26.



36 FISH COMPASS

A type of compass used in the Islamic world is called the fish compass. *Zahr al-Bāsātīn fī 'ilm al-Mašātīn*, written by the Egyptian scholar Muḥammad b. Abi Bakr al-Zarkhurī in 802 AH (1399-1400 AD) gives information about this compass. It is reported that a "fish" made of chill wood or gourd, with a magnetic needle inside, is covered with tar or wax so that it does not absorb water, and placed on the water in a disk to float.[147]

Our model was built according to the description and drawings in the work.[148]

147 Petra G. Schmidl, "Two Early Arabic Sources on the Magnetic Compass", *Journal of Arabic and Islamic Studies* 1 (1997), p. 86.

148 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 3, p. 57.

RASULID SULTAN AL-MALIK AL-AŠRAF'S

37 OLDEST INSTRUCTIONS FOR A MAGNETIC COMPASS

The Rasulid Dynasty, which ruled in Yemen between 1231-1454 AD, is famous for the fact that many members of the dynasty were scientists. Some of the works on astronomy, medicine, agriculture and linguistics written by the members of the dynasty have survived to the present day. The third member of the dynasty, al-Malik al-Ašraf ʿUmar b. Yūsuf is an important figure that is mentioned frequently in the history of science, although not in political history.

An astrolabe built personally by al-Ašraf, who was a good astronomer in addition to being a ruler, his treatise on the making of astrolabe and sundial and his ijahzas (permissions to teach) have survived to the present day. The treatise, whose three complete copies are at present in Cairo, Tehran and Berlin, also includes a short chapter on making a water clock, making a magnetic compass and determining the direction of the qibla.[149]

In the *Risālat at-Ṭāsa* section of this treatise, al-Ašraf describes the making of a floating type of water-powered compass made of brass in the form of a bowl. There is a division for intervals of one and five degrees on the upper surface of the bowl, starting from zero at the north and south points and going up to ninety degrees and ending at the east and west points. The bowl needs to be filled with water before use. A magnetic needle, a straw or a similar stick of the same length as the needle must be inserted through the middle of the bowl and left on the surface of the water. The bowl must be placed on a flat surface in a place where there is no wind.[150]

These instructions for making a compass are the oldest instructions for building an Islamic compass that have survived to the present day. The model we have was built based on the instructions in the work.[151]

149 Schmidl, "Two Early Arabic Sources", pp. 81-132.

150 Schmidl, "Two Early Arabic Sources", p. 100.

151 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 3, p. 58.

NAVIGATION INSTRUMENT USED IN THE INDIAN OCEAN AND THE RED SEA:

38 KAMAL

The Kamal is a traditional navigation instrument used by sailors in the Indian Ocean, consisting of a wooden plate and a string attached to it in the center.[152] Apart from the references in Islamic maritime literature by Ibn Māğid and Sulāimān al-Mahrī, Ottoman sailors such as Pīrī Reʾīs and Sīdī ʿAlī Reʾīs have also mentioned this instrument.[153]

The major method used by sailors for navigation in the Indian Ocean was to determine latitude by measuring the altitude of Polaris. The altitude of Polaris was measured in a unit called isbaʿ, meaning finger or finger width. Two different units, called *tirfa* and *zam*, were used for distances. These two different types of units were used in correlation with each other. For example, an increase or decrease of one degree in the altitude of Polaris corresponded to a distance of *8 zam.*[154] The instrument called Kamal was used to measure the altitude of Polaris.

The mathematical working principle of this instrument, which is very simple in structure and use, is based on simple trigonometry. To take the measurement, the user holds the plate upright and positions the plate in the visible opening between the horizon line and Polaris.[155] The string in the instrument must be held between the user's teeth to keep it straight.
Since the string and the plate will create an isosceles triangle, the geometric ratios will help reveal the altitude of Polaris and therefore the latitude. The drawback of this instrument is that it is only precise at small angles.[156]

Moreover, since each plate can be used in a certain latitude range, Kamal was developed to allow for multiple plates. For example, in his *Kitāb-i Baḥrīye*, Pīrī Reʾīs (d. 1554) mentions an instrument with 12 plates. Sīdī ʿAlī Reʾīs, on the other hand, refers to a nine-plate type kamal in his work *K. al-Muhīt.*[157]

Although the Kamal is a nearly one thousand-year-old instrument, it is still used for navigation in kayaking today; its making and use are described in kayaking handbooks.[158]

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152 Gaye Danışan Polat, "Kamal, An Instrument of Celestial Navigation in the Indian Ocean, as Described by Ottoman Mariners Piri Reis and Seydi Ali Reis", *Osmanlı Bilimi Araştırmaları*, XIX/1 (2017), pp. 1-12. For further literature on the use and history of the Kamal instrument, see: José Manuel Malhão, "The Stellar Compass and the Kamal: An Interpretation of its Practical Use", *Academia de Marinha*, 2003; Sayyid Qudratullah Fatimi, in "History and the Development of the Kamal": H. B. Ray & J-F. Salles, *Tradition and Archeology: Early Maritime Contacts in the Indian Ocean*, Manohar Publishers, Delhi, 1996.

153 Polat, "Kamal, An Instrument", pp. 3- 11.

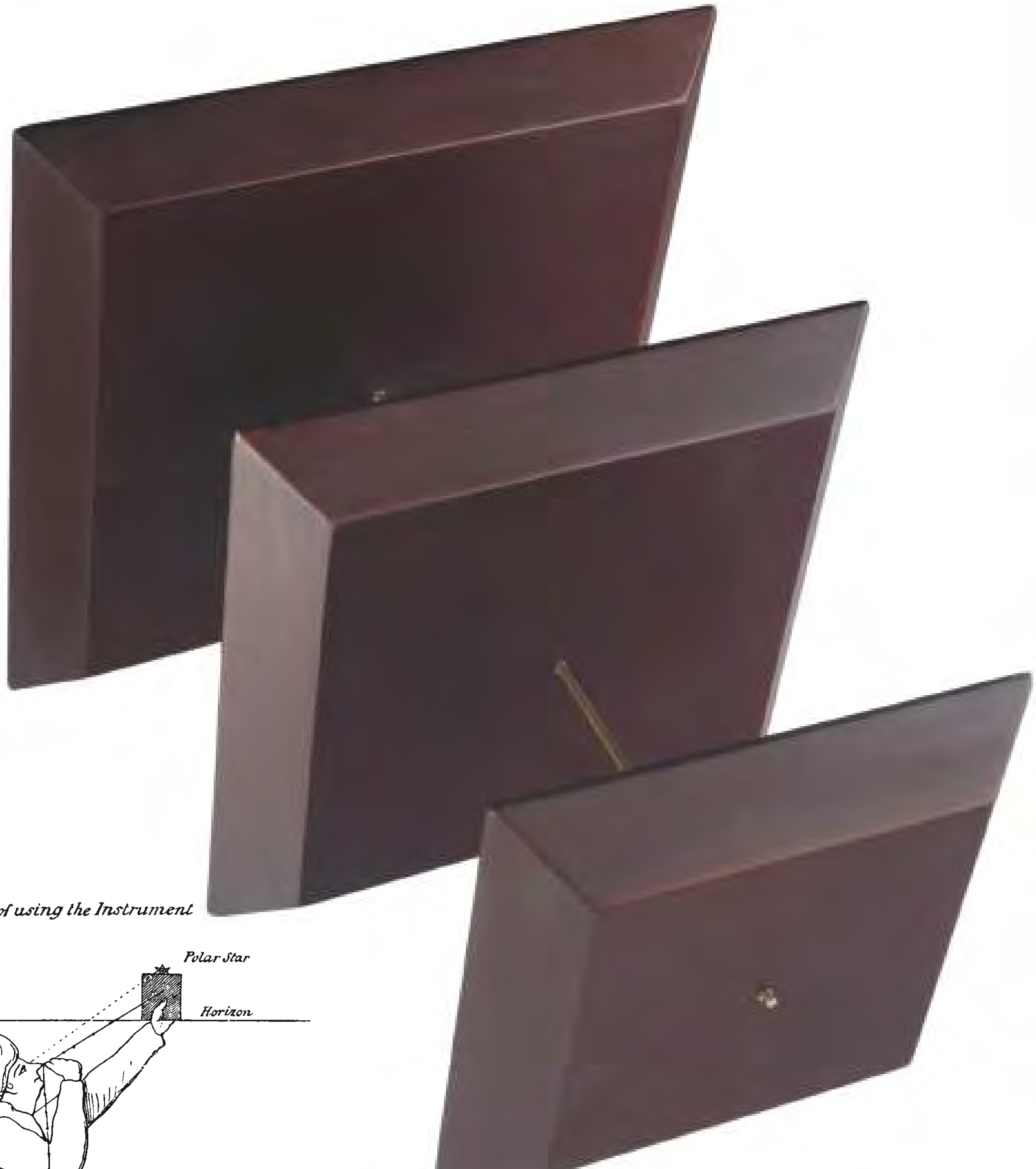
154 Polat, "Kamal, An Instrument", p. 3.

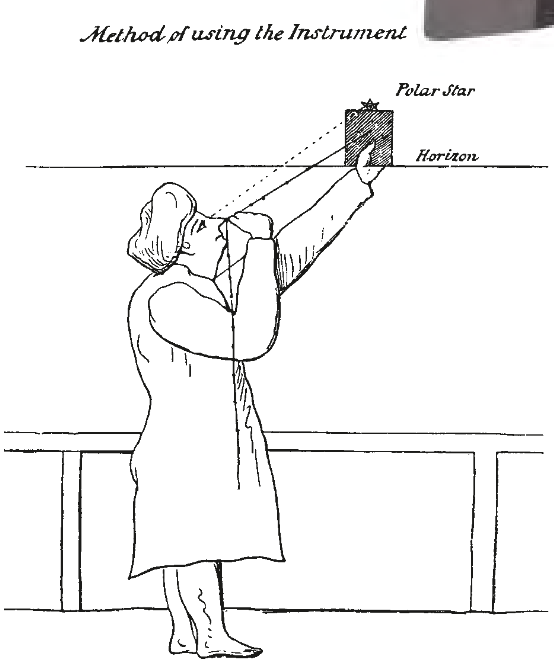
155 Polat, "Kamal, An Instrument", p. 2.

156 Polat, "Kamal, An Instrument", p. 3.

157 Polat, "Kamal, An Instrument", pp. 4-10.

158 For an example, see: Shelley Johnson, *The Complete Sea Kayakers Handbook*, 2nd edition, McGraw-Hill, 2011.





A drawing showing the use of Kamal according to H. Congreve

39 DĀW VESSEL

Dāw vessels, which have been used in the Gulf region since ancient times, form the backbone of fishing in the Red Sea region and the Indian Ocean. Built without using nails, yet surprisingly sturdy, these ships were used on long trade voyages of thousands of kilometers from the Persian Gulf or Oman to Beijing and Indonesia. The source describing these transoceanic voyages with Dāw vessels in the most detailed way is the work titled *Akhbār al-Ṣīn wa 'l-Hind*, one of the oldest travelogues written in Islamic civilization whose only copy is in the Paris National Library.[159] Attributed to a person by the name Sulaimān al-Tağir, this work depicts a voyage on a vessel from the Persian Gulf, first to India and then to China. One of the most interesting Islamic sources about China, this work is also the oldest Islamic source presenting information about tea. The fact that transoceanic voyages to the East are featured not only in travelogues but also in literary narratives is a clear indication of how common these voyages were at that time. For instance, when examined in detail, the Sailor Sinbad stories that are considered a part of the Arabian nights stories today, are actually a part of a narrative tradition in Islamic literature, and despite their fantastic elements, they essentially narrate the route mentioned in Sulaimān al-Tağir's travel book.[160] Dāw vessels are still manufactured and used today while the voyages that cross the oceans now only remain in old travel books.

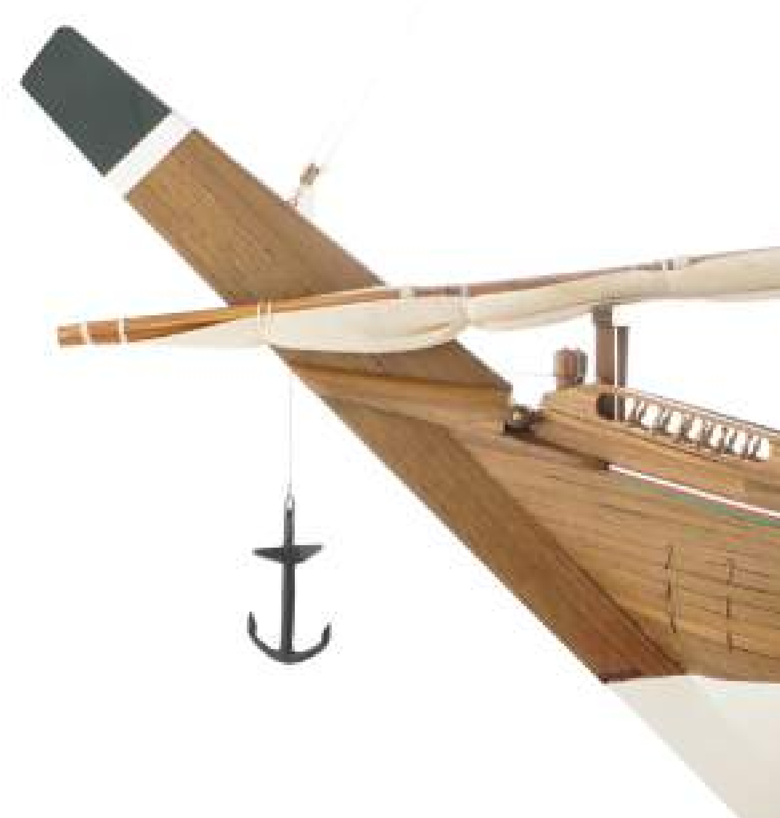
The longest voyage on a Dāw vessel in the modern era was undertaken by adventurer and marine traveler Tim Severin in 1979. In order to prove that the Sinbad stories were factual, Severin built a Dāw vessel using ancient methods and materials under the sponsorship of the Sultan of Oman, Qaboos, and traveled from Oman to China with this ship. Wishing to offer live evidence for the authenticity of the voyages in Sinbad's stories, Severin conveyed his experiences in his book *The Sinbad Voyage.*[161]

159 The only known copy of this work is registered in the National Library of France as Arabe 2281. For an online copy of the work, see: https://gallica.bnf.fr/ark:/12148/btv1b11002084p.image. For general information about the work and its author, see: Osman Cilacı, " *Ahbârü's- Sîn Ve'l-Hind* ", DİA, Vol. 1, p. 493. For the Turkish translation of the work, see: Ramazan Şeşen (trans.), *Doğunun Kalbine Seyahat: Çin ve Hind Ülkeleri ve Hatıraları*, Yeditepe Publications, 2012.

160 Ulrich Marzolph, "Sindbād (the sailor)", in *Encyclopaedia of Islam*, Vol. 9, pp. 638-640.

161 Unfortunately, this work has not been translated into Turkish yet. For the English original, see: Tim Severin, *The Sinbad Voyage*, Putnam, 1982.

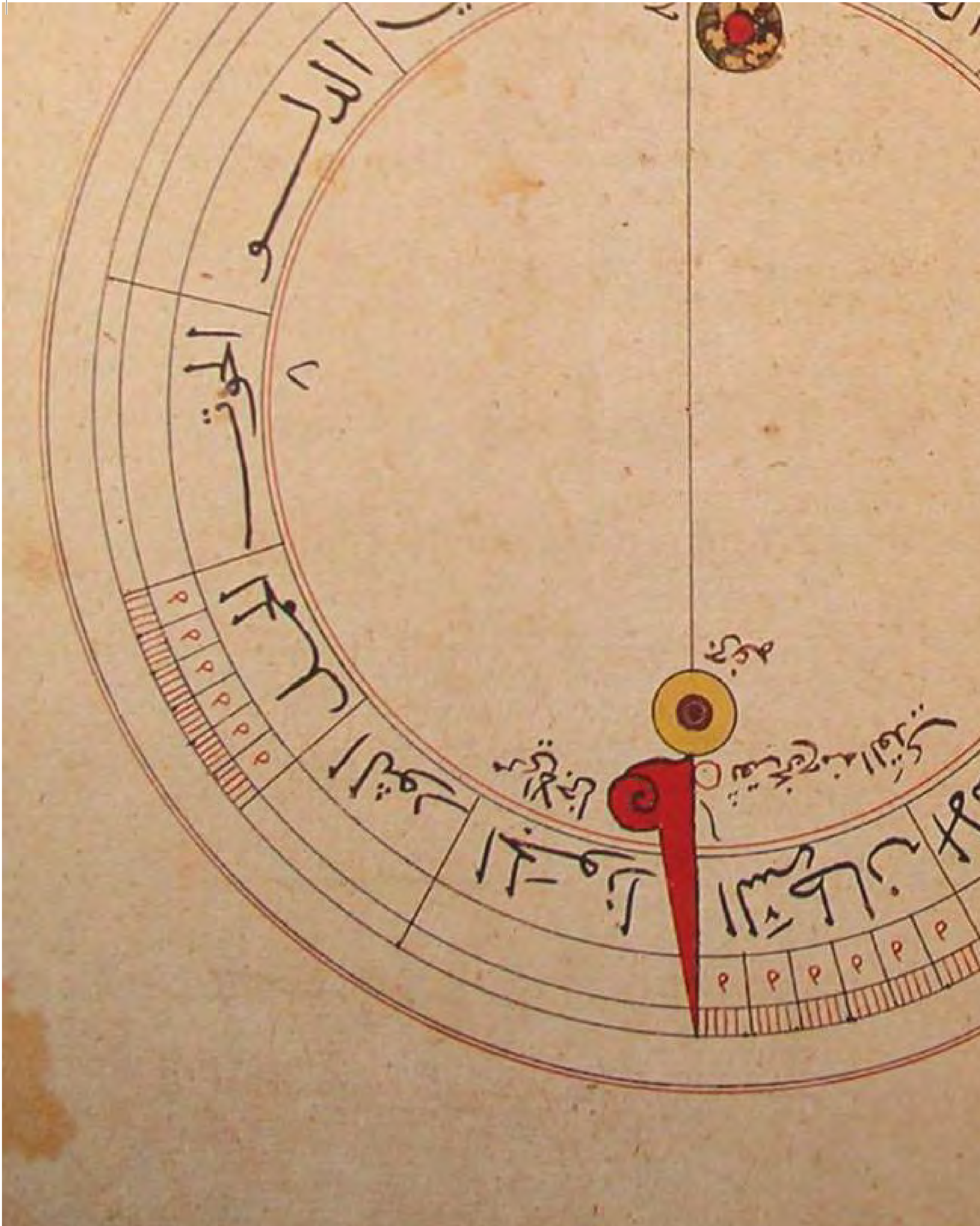
Nearly 20 years after Tim Severin's perilous voyage full of adventures, another substantial piece of evidence for these long voyages on Dāw vessels was discovered by fishermen off the Indonesian island of Belitung. Located in the depths of the sea 1.5 km off the island of Belitung, An Arab Dāw vessel, which is understood to have sunk during a voyage in the 9th century, has made a worldwide impact not only with its distance from its homeland, but also with the valuable items it contained.[162] This ship, purchased by the Singapore government for $32 million, is on display at the Asian Civilizations Museum in Singapore, along with 55,000 Tang period ceramics and other valuable objects. Furthermore, as a joint project between the governments of Oman and Singapore, the Belitung shipwreck was faithfully reconstructed in Oman and set out on a one-off journey from Oman to Singapore.[163] Known as the "Jewel of Muscat", this vessel is also exhibited in the aforementioned museum.[164]



162 An article about this shipwreck was published in the June 2009 issue of *National Geographic* magazine. For another source about the shipwreck, see: A. Chong & S. A. Murphy, *The Tang Shipwreck: Art and exchange in the 9th century*, Asian Civilizations Museum, 2019.

163 For the official website of this project see: https://jewelofmuscat.tv/background/the-project/. The Arabic and English versions of the 130-page book describing the project are available for download at the "The Jewel Book" section of this website.

164 https://www.nhb.gov.sg/acm/galleries/tang-shipwreck



Clocks

THE RASULID SULTAN AL-MALIK AL-AŠRAF'S

40 SUNDIAL

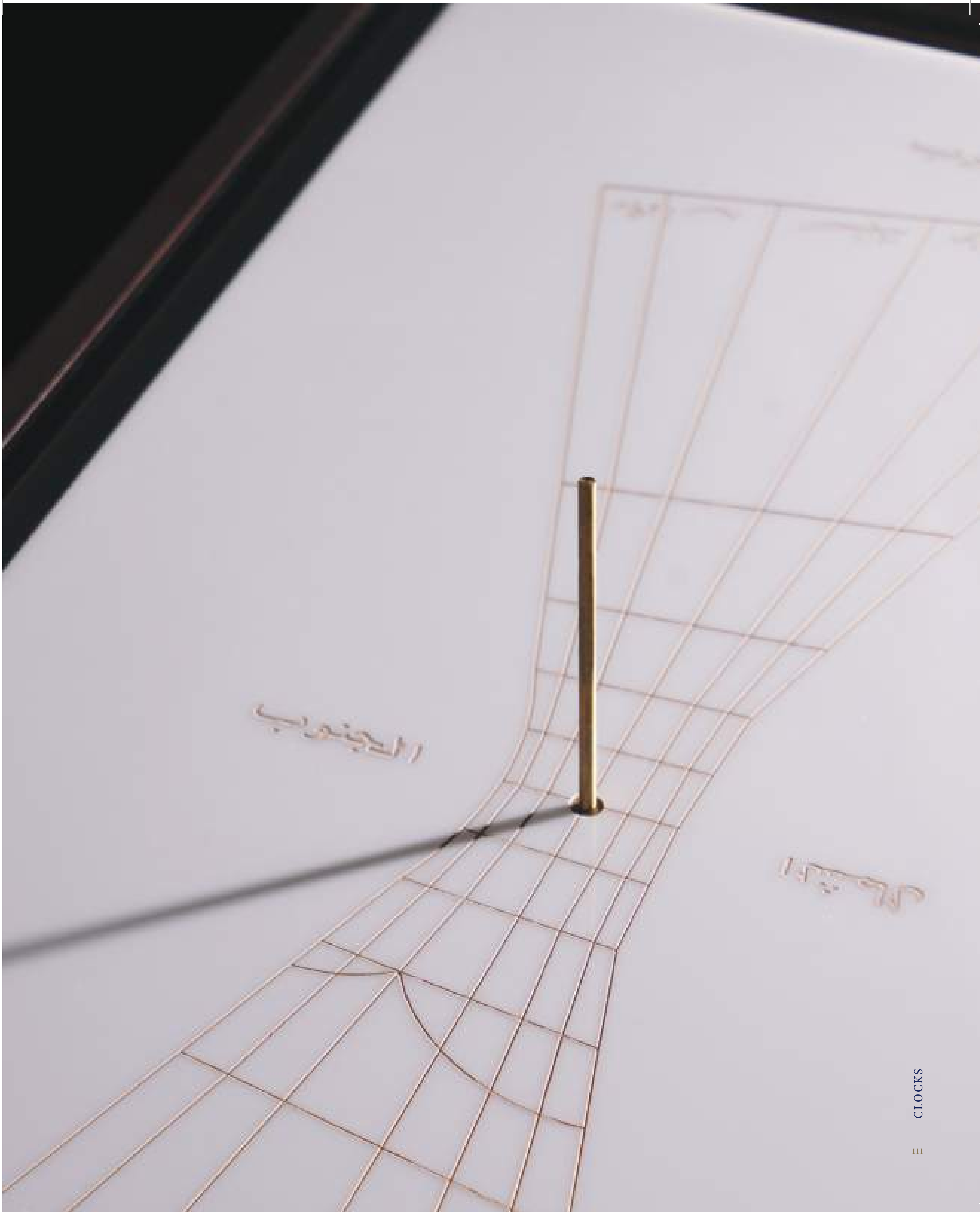
Many members of the Rasulid Dynasty, which ruled in Yemen between 1231 and 1454, were also scientists. Some of the works on astronomy, medicine, agriculture and linguistics, written by the members of the dynasty, have survived to the present day.

The astrolabe, personally made by the third member of the dynasty, al-Malik al-Ašraf, is now exhibited in the Islamic Art section of the Metropolitan Museum in New York. Al-Ašraf's work on the construction of astrolabes, sundials and magnetic compasses is preserved in the Egyptian National Library under TR 105. The second part of this work deals with the construction of horizontal sundials and presents the tables used to draw the hourlines on sundials.[165]

This model was built using a drawing from the manuscript in Cairo.[166]

165 King, *In Synchrony with the Heavens: Vol 2*, Part XIVa, p. 639. An image of the drawing in the manuscript can be found on page 82 of this work.

166 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 3, p. 87.


الجنوب

NŪRADDĪN ZANGĪ'S

41 PORTABLE SUNDIAL

The little information about sundials of antiquity in the works of early Islamic science history is probably due to the fact that they were very simple and widely available.[167] There is no doubt that these instruments mentioned in only a few works from the 9th or 10th centuries, were very well known.[168]

The locust's leg (sāq al-ǧarādā), a type of portable sundial, is a vertical rectangular sundial with a horizontal gnomon (rod). These instruments, which were made relatively small to be portable, are called locust's legs as this word describes a modest gift in Islamic culture ("pāy-i malaḫ" in Persian and "çekirge budu" in Turkish).[169] When this sundial is turned towards the Sun, the shadow of the gnomon shows the time on the plate. This sundial was built for Nūraddīn Maḥmūd b. Zangī by Abu l-Faraǧ ʿĪsā, a student of al-Qāsim b. Hibatallah al-Asṭurlābī, in 554 AH (1159/60 AD). The only extant specimen is preserved in the National Library of France.[170]

Our model was built according to the description and drawings in the work.[171]

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167 Charette, *Mathematical Instrumentation*, p. 145.

168 Charette, *Mathematical Instrumentation,* p. 145.

169 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 3, p. 90.

170 For a detailed analysis of this instrument, see: Paul Casanova, "La Montre du Sultan Noûr ad dîn l'Hégire = 1159-1160) Syria", *Revue d'Art Oriental et d'Archeologie* (*Paris*), Reprint: Islamic Mathematics and Astronomy series, Vol. 88, Frankfurt 1998, pP. 242-262.

171 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 3, p. 90.

ANDALUSIAN MUWAQQIT IBN AR-RAQQĀM'S

42 PORTABLE SUNDIAL

Ibn ar-Raqqām's full name is Abū ʿAbdallāh Muḥammad b. Ibrāhīm b. ʿAlī b. Aḥmad b. Yūsuf al-Mursī al-Andalusī al-Tūnisī al-Awsī (d.715/1315). As it can be understood from the nisba al-Mursī in his name, he was probably born and raised in the city of Murcia in Andalusia. He migrated to North Africa after King Alfonso X of Castile captured the city.[172] After living in the city of Bejaia (Bougie) for some time, he went to Granada upon the invitation of the Nasrid ruler Muhammad II (1273-1302 AD), and lived there until his death on May 27, 1315 AD.

An astronomer, mathematician, and physician, Ibn ar-Raqqām wrote 11 known works. Three of these works are related to medicine, one to theology, one to mathematics and six to astronomy. His works on astronomy include an instructive poem on the astrolabe, "ru´yat al-hilāl" (sighting of the new moon), and three zījes (astronomical handbook with tables).[173] These three zījes by Ibn ar-Raqqām are based on Ibn Isḥāq al-Tūnisī's (d. 619/1222) incomplete zīj, which, in turn, was based on the work of az-Zarqālī.[174] In this context, the zījs by Ibn ar-Raqqām document the spread of az-Zarqālī's ideas on astronomy in the Maghrib and Andalusia.[175]

Another work on astronomy by Ibn ar-Raqqām is his work on sundials, titled *Risāla fī* ʿIlm *aẓ-ẓilāl*, that is, *Treatise on the Science of Shadows*, which he wrote in 1280-1281.[176] In this work, Ibn ar-Raqqām describes the construction of many different sundials using projection techniques on a plane.[177] Consisting of a sundial drawn on a circular disk and a compass to accurately set the direction of the sundial, this instrument is suspended by silk threads.[178]

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172 Ahmet Özel, "Ibnü´r-Rakkām", DİA, c. Annex-1 (2016), pp. 618-619, EI3; Josep Casulleras, "Ibn al-Raqqām", online 4 April 2021; Josep Cassuleras, "Ibn al-Raqqām", BAE, pp. 563-564; EHSTM, "Ibn al-Raqqām", p. 1097.

173 For detailed information on Ibn ar-Raqqām's zījs, see: E. S. Kennedy, "The Astronomical Tables of Ibn al-Raqqām: Scientist of Granada", *Zeitschrift für Geschichte der Arabischen-Islamischen Wissenschaften*Vol. 11 (1997), pp. 35-72.

174 Julio Samsó, "Andalusian Astronomy in 14th Century Fez: Al-Zīj Al-Muwafiq of Ibn ʿAzzūz al-Qusanṭīnī", *Zeitschrift für Geschichte der Arabischen-Islamischen Wissenschaften* Vol. 11 (1997), Frankfurt am Main, pp. 73-103.

175 Julio Samsó, "Ibn al-Raqqām", in: Selin H. (eds.) *Encyclopaedia of the History of Science, Technology, and Medicine in Non- Western Cultures*. Springer, Dordrecht 2008, p. 1097.

176 The only surviving manuscript of the treatise is in the Escorial Library in Spain, in the journal number 918, as the 11th treatise (fol. 68b-82a). The work was prepared in a critical edition by the Spanish historian of science Joan Carandell and published with a Spanish translation. See: Ibn al-Raqqam & Joan Carandell, *Risala Fi Ilm Al-Zilal*, Universidad de Barcelona, Instituto "Millás Vallicrosa" de Historia de la Ciencia Árabe, Barcelona 1988.

177 Samsó, "Ibn al-Raqqām", p. 1097.

178 Sezgin*, İslam'da Bilim ve Teknik*, Vol. 3, p. 114.

THE MOST SOPHISTICATED SUNDIAL: IBN AS-ŠAṬIR'S

43 DAMASCUS UMAYYAD MOSQUE SUNDIAL

The most important astronomer of the 14th century and the chief muwaqqit of the Umayyad Mosque in Damascus, ʿAlī b. Ibrāhīm b. Muḥammad Ibn aṣ-Šāṭir is best known for the new astronomical instruments and planetary theories he developed.[179]

The 1x2 meter monumental sundial that he produced for the Umayyad Mosque is the most advanced sundial in Islamic civilization.[180]

This sundial, which actually consists of three sundials, was found broken into three parts during the excavations carried out in the drainage system of the Umayyad Mosque in 1958. The sundial probably broke while muwaqqit Muḥammad Ibn Mūsṭafa aṭ-Ṭantāwī tried to make corrections to it, subsequently aṭ-Ṭantāwī had a copy made in 1293 AH (1876/77).

The original pieces are kept in the garden of the Archaeological Museum of Damascus today.[181] The copy commissioned by aṭ-Ṭantāwī was in the al-ʿArūs minaret on the north side of the Umayyad Mosque until recently, but today there is no information about its whereabouts.

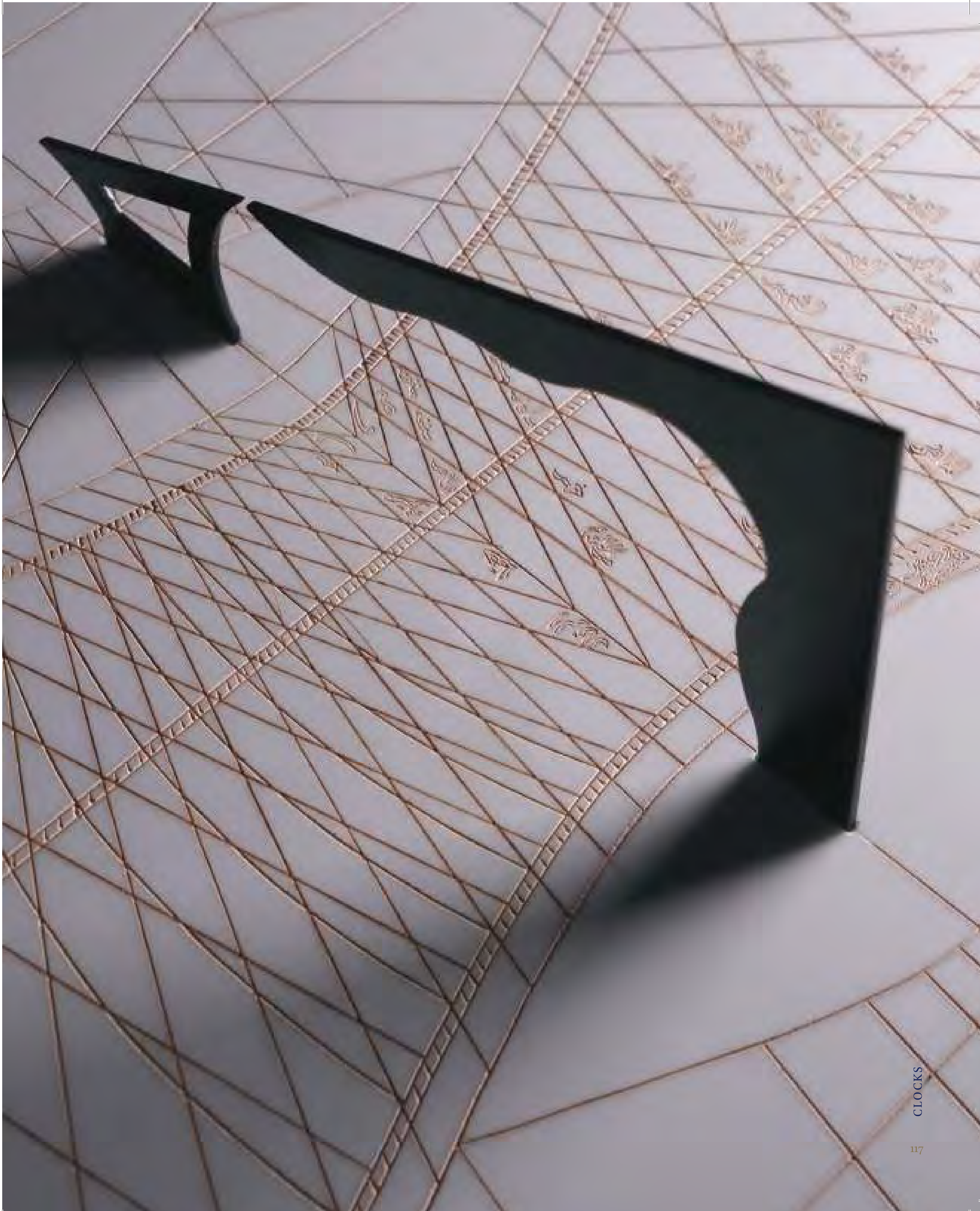
Our model is based the original in the museum.[182]

179 David A. King, "Ibn al-Shāṭir", pp. 569-570.

180 A technical analysis of this sundial were carried out by David A. King. See: King, *In Synchrony with the Heavens:* Vol 2. Part XIVb, pp. 712-715.

181 King, "Ibn al-Shāṭir", p. 712.

182 Sezgin *, İslam'da Bilim ve Teknik,* Vol. 3, pp. 91-92.



IBN AL-MUHALLABĪ'S

44 DOUBLE GNOMON SUNDIAL

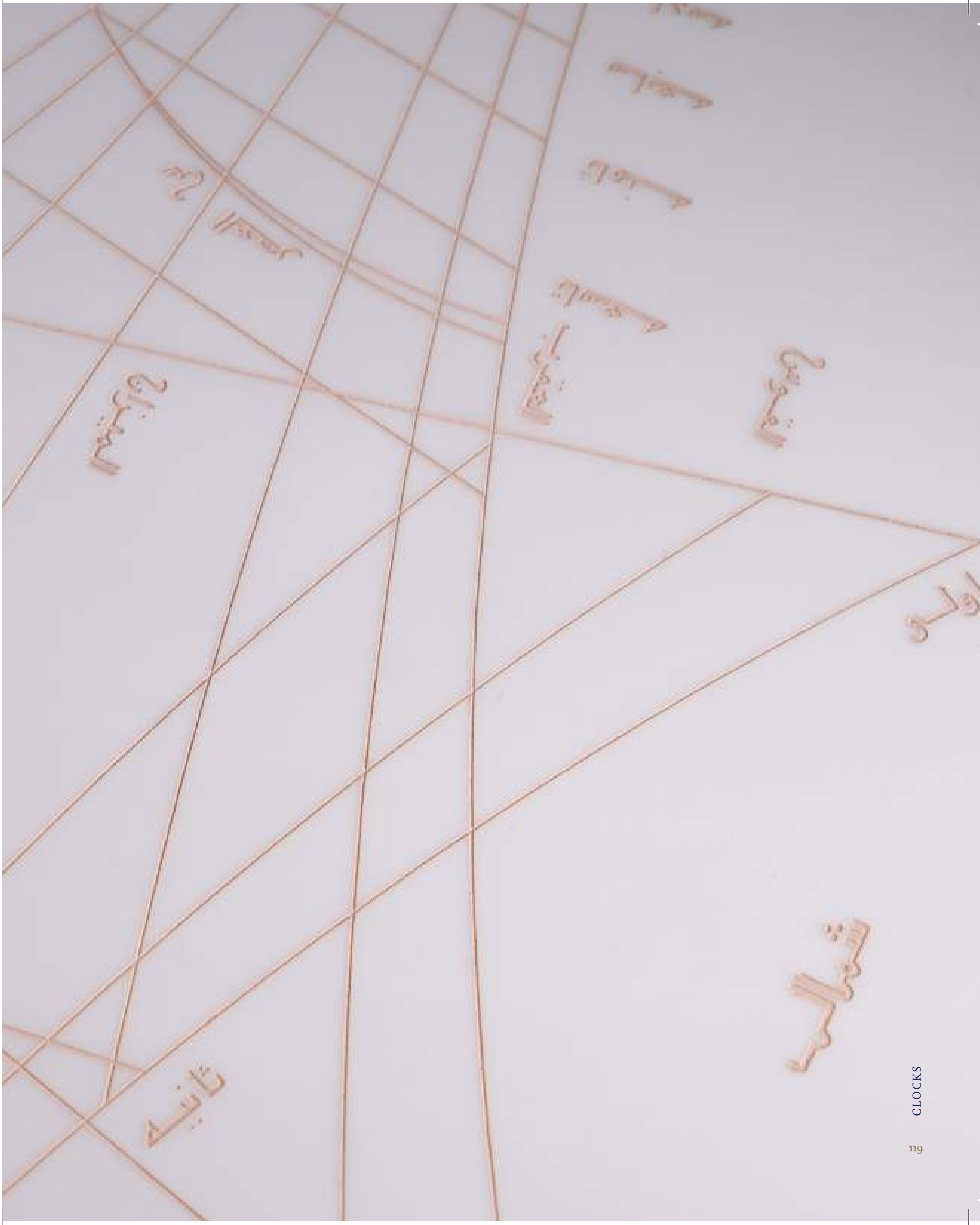
In his *'Umdat ad- Ḏākir li-Waḍ' Ḫuṭūṭ Fāḍl ad-Dā'ir* he penned in 849 AH (1426 AD), a copy of which is currently preserved in the Chester Beatty Library in Dublin as number 3641, the Egyptian muwaqqit Zainaddīn 'Abdarrahmān b. Muḥammad Ibn al-Muhallabī al-Mīqātī refers to the production of a type of sundial distinct from the regular butterfly-shaped sundial types. The new figure, which consists of a two-half butterfly-shaped figures cut through the center and overlapped, takes up less space, but unlike the butterfly-shaped sundials, it works with two gnomons instead of one. An example of this sundial model was found by the scientists Napoleon brought with him in his Egypt Campaign. An engraving was prepared and published in Napoleon's famous work *Description de l'Egypt*.[183] Another specimen was built by the astronomer Ḫalīl ibn Ramtaš in Cairo in 726 AH (1325/26) and is now in the Victoria & Albert Museum in London.[184]

Our model was built according to the description and drawings in the work.[185]

183 L. Janin, David A. King, "Le Cadran Solaire de la Mosque d'Ibn Tulun au Caire", *Journal for the History of Arabic Science*, 2/1978/331-357. For a reprint: David A. King, *Islamic Astronomical Instruments*, Variorum, London 1987. Also see image: David A. King, *In Synchrony with the Heavens: Vol 2, Instruments of Mass Calculation*, Part X, Chapter Seven, p. 87.

184 King, *In Synchrony with the Heavens*, p. 88.

185 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 3, p. 93.



AL-ǦAZARĪ'S

45 PORTABLE WATER CLOCK WITH A SCRIBE

In the 13th century, in his *Al-* Ǧāmiʿ *Bain al* ʿilm *wa-l-* ʿAmal*,* The engineer al-Ǧazarī who worked at the service of the Artuqid Ruler Sultan aṣ-Ṣāliḥ Abu l-Fatḥ Maḥmud b. Muḥammad b. Qarā-arslān in Cizre (around 600/1200), writes that the sultan commissioned him to build a sturdy clock that shows the time conveniently and can be taken on journeys.[192] In response to this request, al-Ǧazari built a water clock with a beaker on which a scribe sits. This clock, which he describes as "the fifth form of the first type" in his work, works with a hidden float mechanism. The scribe figure, which is moved by the float that goes down when the water in the chamber drains from a specially created hole at the base of the beaker, turns on the axis and shows the time with the stick in his hand.[193]

Our model was built according to the description and drawings in the work.[194]

192 For the Turkish translation of works, see: Şükran Fazlıoğlu, İhsan Fazlıoğlu and Durmuş Çalışkan *, Cezeri'nin Olağanüstü Makineleri: Mekanik Biliminde Bilgi ve Uygulamanın Bağdaştırılması*, Papersense Yayınları, Istanbul 2015. For the English translation: Donald R. Hill, *The Book of Knowledge of Ingenious Mechanical Devices*, Kluwer, Dordrecht 1974. For the facsimile of the work, see: Bedi uz-Zaman Ebû'l-İzz İsmail b. Ar-Razzaz al-Jazari, The *Book on the Knowledge of Extraordinary Mechanical Tools*, Topkapı Palace III. Facsimile of Ahmet, Kültür Bakanlığı Yayınları, 1990.

193 For technical details of the work, see: Fazlıoğlu, Fazlıoğlu and Çalışkan, *Cezeri'nin Olağanüstü Makinaları,* pp. 162-177.

194 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 3, p. 103.

46

AL-ǦAZARĪ'S

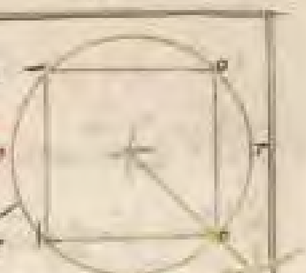
CANDLE CLOCK WITH A SCRIBE

In the first chapter of his *Al-* Ǧāmiʿ *Bain al* ʿilm *wa-l-* ʿAmal where he discusses clocks (the 8th form of the 1st type) al-Ǧazarī refers to the making of a clock which he defines as "the scribe's clock, in which the passage and divisions of fixed (equal) hours are learned with the help of candles".[195] The clock in question is a candle clock that displays the passage of time with two different indicators in terms of hours and minutes.

The counterweight mechanism inside the clock moves downwards as the candle melts and becomes lighter and the counterweight becomes heavier compared to the candle. Since the weight is connected to the post under the candle's base with a pulley system, the weight pulls the post and the base up as it goes down. Thus, although the candle melts and its base rises, its burning end remains at the same height. There is also a ball channel connected to the post under the candle base. Moving upwards with the base of the candle, the post also pulls the balls upwards and for every hour one ball corresponds to the mouth opening of a hawk. The ball enters the beak of the falcon thanks to a directional cover that pushes the ball towards the opening on the side and falls on the terrace of the clock. At the same time, while the weight of the counter mechanism moves down, it pulls a string connected to the scribe on the table and the pulley below it, and thus the scribe turns.

This mechanism allows the exact (fixed/equal) hours to be known from the number of balls, while minutes are read from the circular scale as indicated by the scribe.

195 Fazlıoğlu, Fazlıoğlu and Çalışkan, Cezeri'nin Olağanüstü Makinaları, pp. 222-232. Durmuş Çalışkan, *Cezeri'nin Olağanüstü Makineleri: Herkes İçin Cezeri*, Babil Kitap, Istanbul 2019, pp. 157-160. Donald R. Hill, *The Book of Knowledge of Ingenious Mechanical Devices*, Kluwer, 1988, pp. 87-89, 253-254.



وان شئنا جعلنا نقطتي ا ب مركزين وبفتح البركار وعلامات ه ح ط ووصلنا خطي ه ح ط يتقاطعان خط ا ح على نقطتي ه ط مركزين وبالبعد دايرتين يتقاطعان على علامتي ل م ووصلنا من ل م وتخرجه الى نقطتي ب د وصل خطوط اب ب ح ح د د ا فيكون مربع ا ح متساوي الاضلاع والزوايا وهذه صورته ٥ وان شئنا جعلنا

علامات ه ح ط مراكزا وادرنا دواير يتقاطع على نقطتي ح د ووصلنا خط د ح تقطع الدايرة على نقطتي ب د وجعلنا خطوط اب ب ح ح د د ا فيكون من ذلك مربع ا ح متساوي الاضلاع وهذه صورته

وان شئنا وصلنا من نقطتي ا ط ح خطين تتقاطعان ا د ونقطتي ح د يتقاطعان على نقطة م ووصلنا بينهما من المركز واخرجناه الى نقطتي ب د وهذه صورته عمل المخمس في دايرة فان قال كيف نعمل

دايرة مخمسا متساوي الاضلاع جعلنا المركز نقطة ر و اخرجنا ا د ح واخرجنا من نقطة ر عمود ر ب وقسمنا ا د بنصفين على نقطة ه وجعلنا نقطة ه مركزا وبعد ه ب علامة ر وجعلنا نقطة ب مركزا وبعد ر علامة ط فيكون قوس ب ط خمس الدايرة فاذا جعلنا قسي ب ط ط ح ح د مساوية لقوس ب ط ووصلنا

على دايرة اب مثلثا متساوي الاضلاع
متساوي الاضلاع واخرجنا من كل
خطا ما يلتقي على نقطة
متساوي الاضلاع وهذه صورته
دايرة مربعا متساوي الاضلاع جعلنا الد
قطريا يتقاطعان على زوايا
فيكون مربع ا ح متساوي
صورته ٥ فان قال كيف نعمل في دايرة
نصف قطر دايرة ا ح مخرج
نقطتي ه د وصل ه د وتجعل نقطة ب مركزا
يتقاطعان على نقطة م ونصل بين
نقطتي ب د ونصل اب ب ح ح د د ا فيكون مربع
الاضلاع وهذه صورته ٥ وان شئنا
كيف ما كانت مثل ثم اخرجنا
ثم نصفت ب د بان نصل بين
من كل منها عمودا الى غير نهاية يتقطع
صورته والشكل في صفحة المقابل ٥

Geometry

(PERGĀR-I SINDĪ)

47 INDIAN COMPASS

Ālāt *al-Raṣadiyye li Zīğ al-*Š*ahin*šāhiyye, which was written in Turkish by the court historian Seyyid Lokman , describes nine observation instruments used in the observatory with miniatures.[199]

An Indian compass is mentioned in the epilogue of the work:

“ *This is the description of the Indian compass used in the building of the aforementioned instruments. This compass, which is a long ruler made of wood, is necessary to draw and record rings and circles. Two pieces of iron pickaxe are placed on the edge of the ruler. The center of one is fixed to the edge of the ruler, the other is placed on the ruler to serve as the compass to be lengthened and shortened along the axis. If the ruler is not used as a compass, it is not called an Indian compass. Among other rulers and necessary things, we have sufficed with the description of the simplest and the most convenient one. Its form can be seen in the picture.*”[200]

Our model was built according to the description and drawings in the work.[201]

199 This work was published by Prof.Mustafa Kaçar, M. Şinasi Acar and Prof. Atilla Bir, together with the facsimile of three copies, transliteration of the text and its translation into modern Turkish. See: Mustafa Kaçar, M. Şinasi Acar and Atilla Bir, XVI. *Yüzyıl Osmanlı Astronomu Takiyüddīn'in Gözlem Araçları:* Âlat-*ı Rasadiyye li Zîc-i* Şehinşâhiyye, Türkiye İş Bankası Kültür Yayınları, Istanbul 2010.

200 Kaçar, Acar and Bir, *XVI. Yüzyıl Osmanlı,* pp. 52-53; For transliteration, see p. 65; for facsimiles pp. 75, 105, 185.

201 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 3, p. 148.

AL-ĞAZARĪ'S INSTRUMENT

48 FOR ESTABLISHING THE CENTRE OF A CIRCLE THROUGH ANY THREE POINTS ON A GLOBE AND A PLANE

In the 13th century, in his *Al-* Ğāmiʿ *Bain al* ʿilm *wa-l-* ʿAmal, the engineer al-Ğazarī who worked at the service of Artuqid Ruler Sultan aṣ-Ṣāliḥ Abu l-Fatḥ Maḥmud b. Muḥammad b. Qarā-arslān in Cizre (around 600/1200), describes the construction of a geometrical instrument as the second form of the sixth type.[202]

al-Ğazarī explains his motive for building this instrument as follows:

"I say that an arc of a circle, which may be one-third, ore one-half (of a circle) or more or less, passes through any three points on the surface of a sphere. Whenever I stated this, some have denied it and asked me to prove it by placing the leg of the compass in the center and passing the other leg through 3 unknown points. There is a randomness here. That is, the straight line reaching from the first point to the second point is divided into two in the middle by a mark. A perpendicular line is drawn over this mark, forming two equal angles equal to the first line. Likewise, a line marked in the middle is obtained between the second and third point; Again, a perpendicular forming two equal angles to the first line is drawn over the mark. This perpendicular line intersects [the first perpendicular] and this is the center. Based on this, I built an instrument that will make it easier to determine any center point and calculate all the narrow and wide angles used. "[203]

Our model was built according to the description and drawings in the work.[204]

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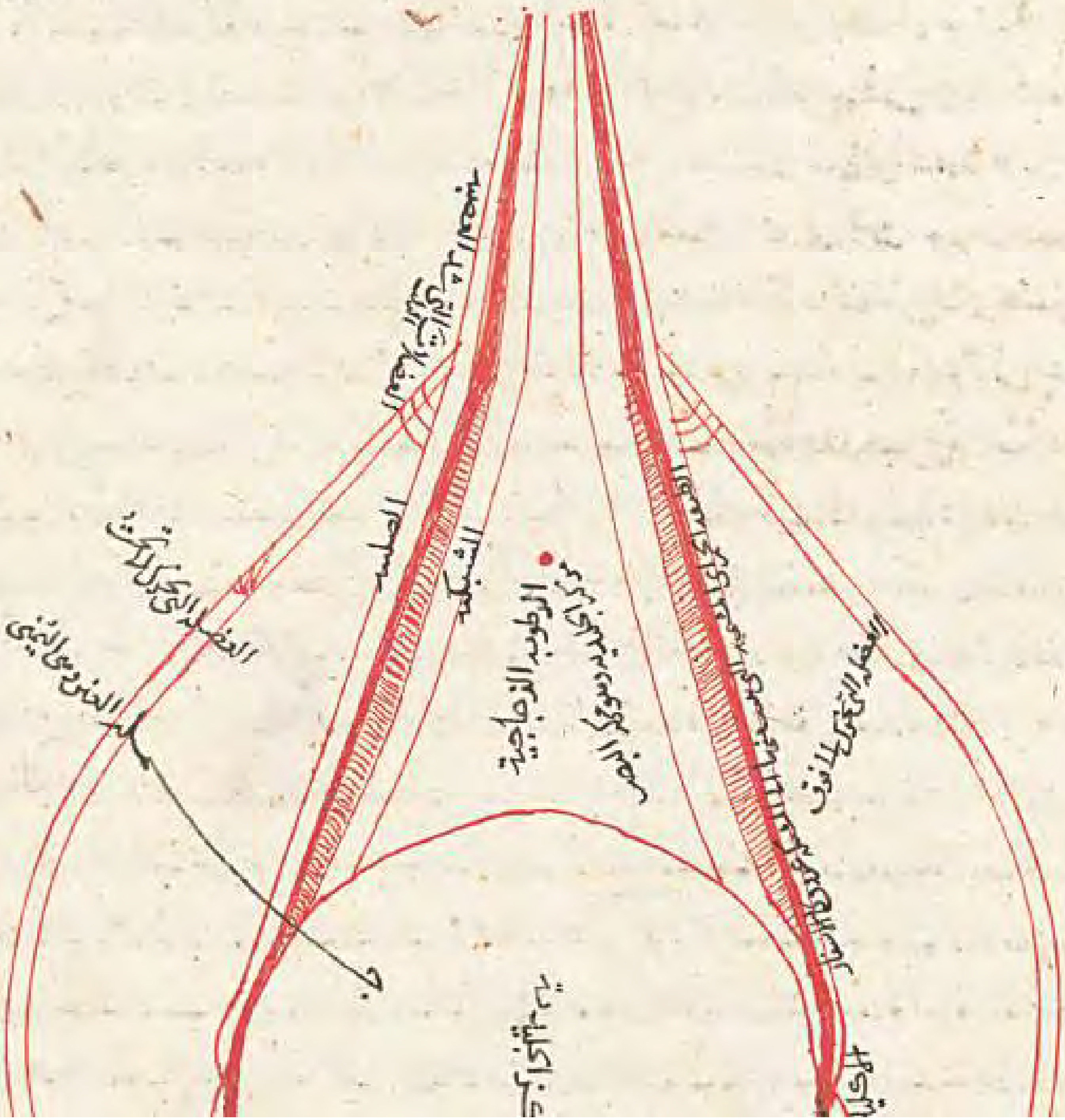
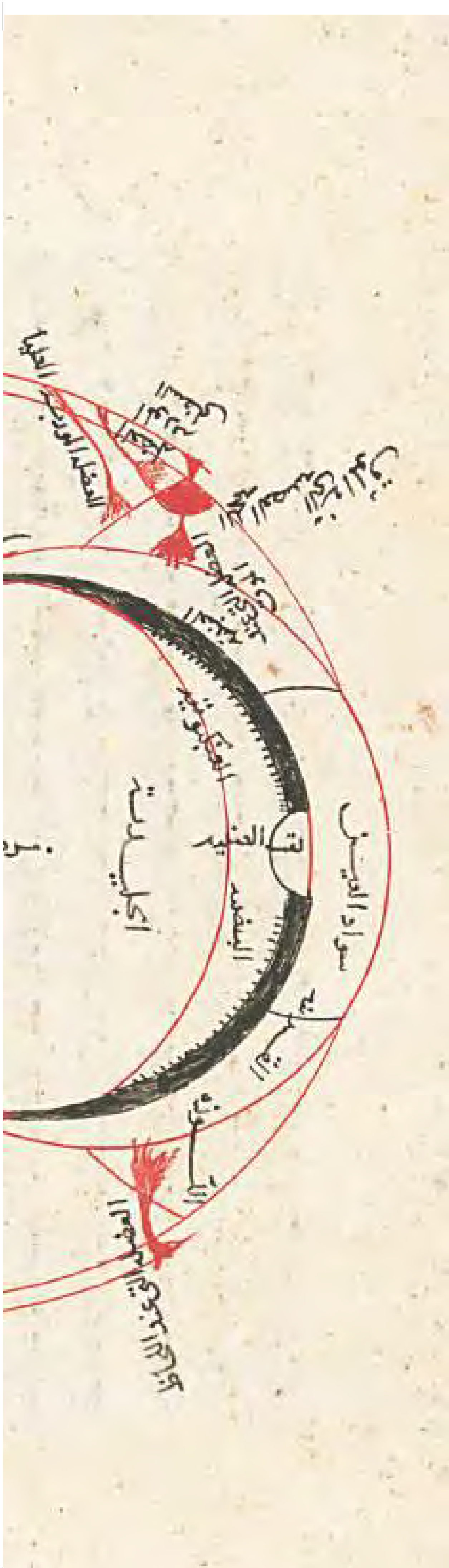
202 Fazlıoğlu, Fazlıoğlu and Çalışkan, *Cezeri'nin Olağanüstü Makineleri*, pp. 122-161. Bedi'uz-Zaman Ebû'l-'İzz İsmâ'îl b. Er-Rezzâz el-Cezerî, *el-Câmi' Beyne'l-İlm ve'l-'Ameli'n-Nâfi' fî Sına'at'il-Hiyal*, translation, analysis and technical explanations: Melek Dosay, Sevim Tekeli and Yavuz Unat, Türk Tarihi Kurumu Yayınları, Ankara 2002, Vol. II, pp. 254-258, 294; Ibn al-Razzāz al-Jazarī, *The Book of Knowledge of Ingenious Mechanical Devices*, translation: Donald R. Hill, Pakistan Hijra Council, Islamabad 1986, pp. 196-198.

203 Fazlıoğlu, Fazlıoğlu, and Çalışkan, *Cezeri'nin Olağanüstü Makineleri*, p. 254.

204 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 3, p. 150.

معاينا لا الا من جهة واحدة ومن اوجب للقياعينا فقد اخطا لانه ليس يمكن ان يسع موضع الدماغ عصب ليخدم
العين في ابصارها لان الحواس بانفعالها يدرك وذلك انما ينالى بلين العصب ولا يمكن ان ينالى اليها من مقدم الدماغ
والا لكان معرضا للاهتزال لبعد المسافة فسبحن من وضع كل شيء بحكمته ما يبلغ به غاية ما خلق له في اعدل صورة و
احسنها واحرز خلقه عن الافات واحصنها وهذه صورة العين بحسب ما يمكن تصويرها على السطح





Optics

USED BY IBN AL-HAİṮAM IN REFLECTION EXPERIMENTS:

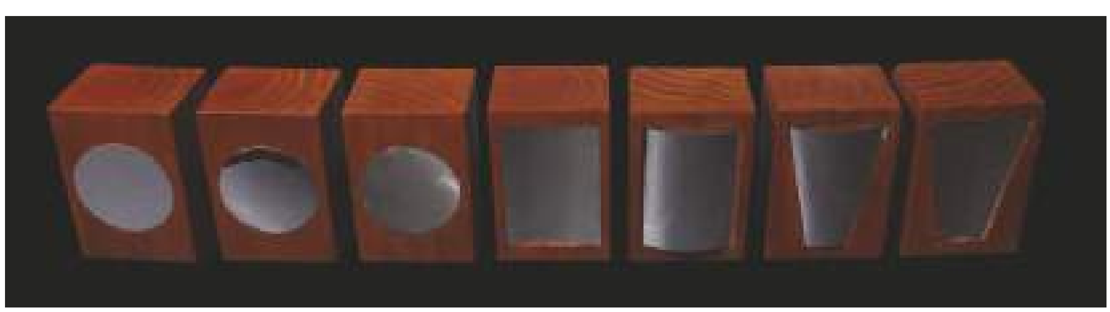
49 "REFLECTION APPARATUS"

There is little doubt that Ibn al-Haiṯam is one of the most important scientists in Islamic civilization. In particular, *Kitāb al-Manāẓir,* his work on optics, broke new ground not only in the Islamic world but also in Europe. The Latin translation of the work was made in the 13th century and published as *Opticae Thesaurus* in 1572. The work continued to be used as an important reference source until the 17th century.

In this work, Ibn al-Haiṯam introduced a new theory by reinterpreting different theories about light and vision that the Islamic civilization inherited from the ancient Greek civilization and supplemented them with new experiments. There are two important theories of vision inherited from antiquity: The extramission theory and the intromission theory. According to the extramission theory, the rays coming out of the eye scatter around like in the shape of a hand and form an image by probing the surroundings. In the intromission theory, the rays reflected from the objects come to the eye from the outside. In his work, Ibn al-Haiṯam describes a series of different experiments in great detail and proves that light moves in a linear fashion, that it reflects from objects in every direction, that the light reflected from the objects reaches the eye and that vision is formed in points.

Ibn al-Haiṯam tackles the reflection of light extensively in the fourth treatise of *Kitāb al-Manāẓir.* He then describes the construction of an experimental instrument, which he calls the "reflection apparatus" (ālat al-inʿikās).[205] The purpose of the instrument is to illustrate the law of reflection with examples. He further shows that this law also applies to reflections and colored rays in cylindrical, conical and spherical mirrors.[206]

Our model was produced according to the description given by Ibn al-Haiṯam.[207]



205 Saleh Beshara Omar, *Ibn al-Haytham's Optics: A Study of the Origins of Experimental Science*, Bibliotheca Islamica, Minneapolis 1977, pp. 107-123; A. Mark Smith, *Alhacen on the Principles of Reflection*, Vol. 1, pp. xviii-xix, pp. 10-19 (Latin text), Vol. 2, pp. 300-308 (English translation). For a recent review of Ibn al-Haiṯam's scientific method, see Sohrab Ghassemi, "Ibn al-Haytham and Scientific Method," Georgetown University (Unpublished doctoral dissertation), Washington 2020.

206 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 3, p. 172.

207 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 3, p. 172.

KAMĀLADDĪN AL-FĀRISĪ'S

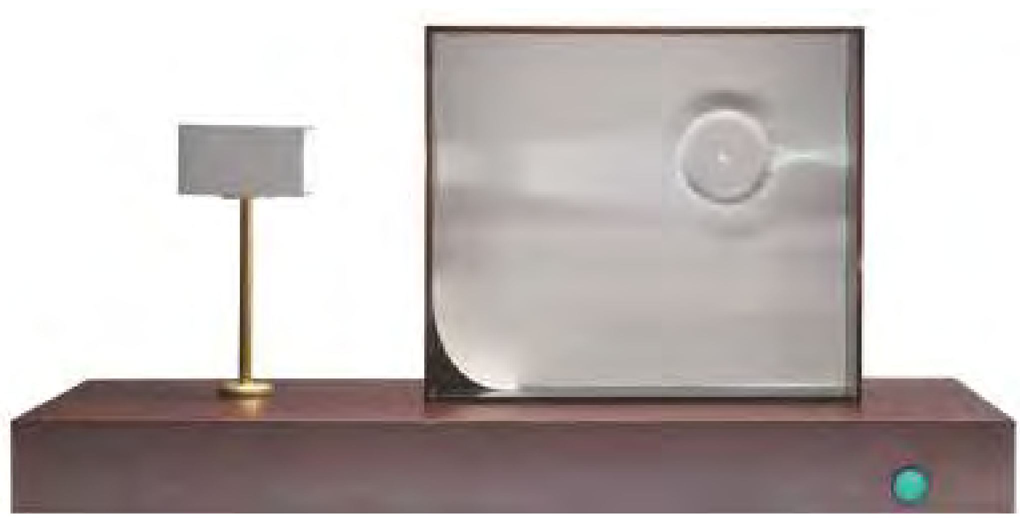
50 RAINBOW EXPLANATION

One day, the famous Islamic scholar Kamāladdīn Abu l-Ḥasan Muḥammad b. al-Ḥasan al-Fārisī (d. 718/1318) visited his teacher Quṭbaddīn aš -Šīrāzī and told him that he had read all the optics books but could not find answers to his questions in them. Upon hearing this, Ḳutbettīn al-Shirāzī said that he saw a very important work on optics in a library in his youth and that he would find it and bring it, even if it was in the Pleiades. After a long time, this work arrived from a distant place and Kamāladdīn al-Fārisi ardently set out to write an annotation to Ibn al-Haiṯam's work.[208]

In the section that deals with the question of how a rainbow is formed in a raindrop in his commentary entitled *Tenḳiḥ al-Manāzır*, al-Fārisī introduces a unique new explanation. This explanation is an important discovery as it is the first accurate mathematical explanation of the formation of the rainbow in the history of science. According to al-Fārisī, the light from the Sun is refracted twice in the raindrop, and when it is reflected once or twice, a rainbow is formed. Al-Fārisī also describes an experimental setup that corroborates this explanation.[209]

Interestingly, Kamāladdīn al-Fārisī not only made a new discovery in the commentary he wrote, but also made Ibn al-Haiṯam's work famous. The Islamic world got to know Ibn al-Haiṯam especially through this commentary by al-Fārisī. Although only one complete copy of Ibn al-Haiṯam's *Kitāb al-Manāẓir* has survived until our day, there are 15 copies of al-Fārisī's commentary that have survived.[210]

The transparent circular disc represents a raindrop in the model in our collection.[211]

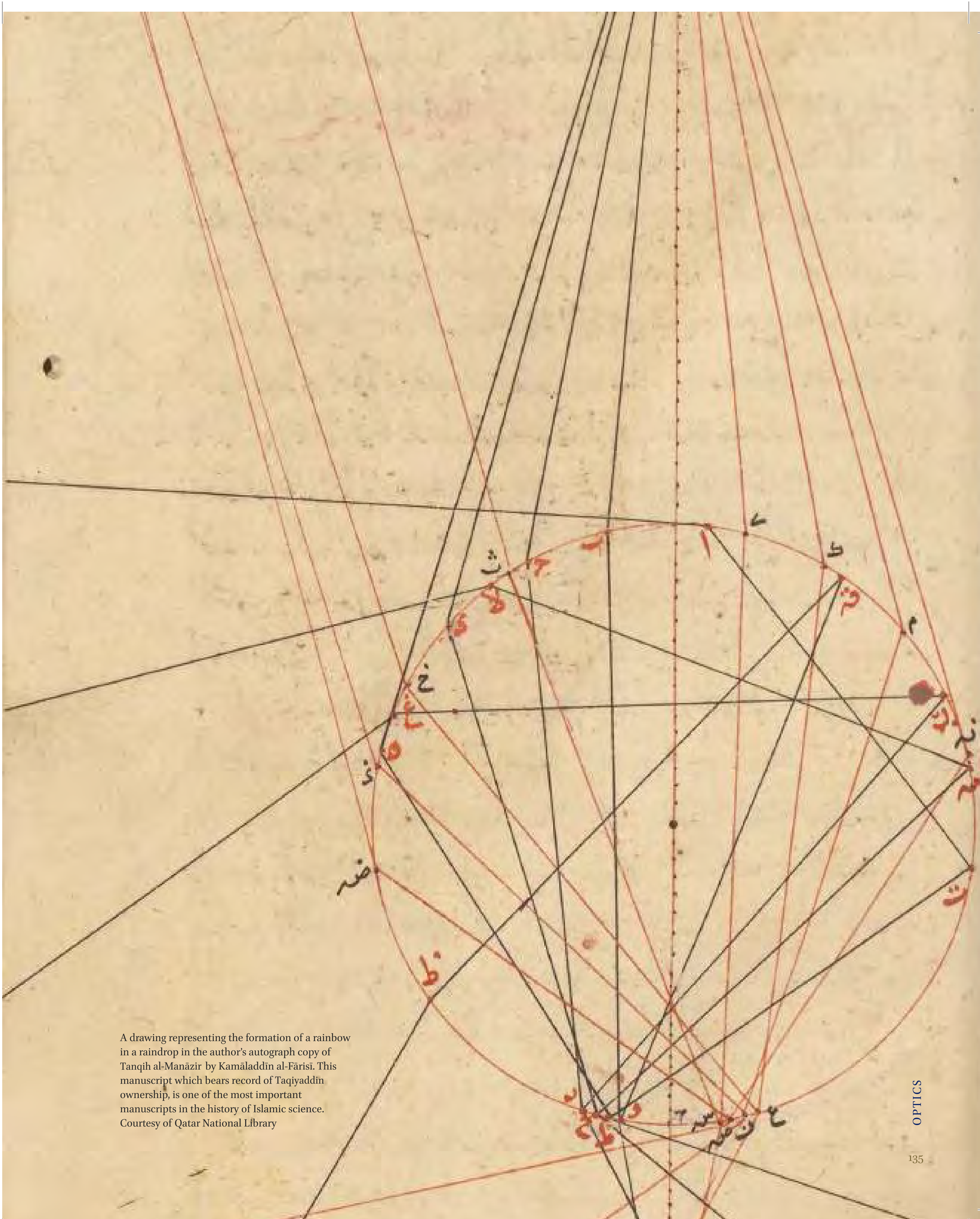


208 A. I. Sabra, "The 'Commentary' That Saved the Text. The Hazardous Journey of Ibn al-Haytham's Arabic Optics", *Early Science and Medicine* 12 (2007), pp. 117-133, 119, 121-122.

209 Hüseyin Gazi Topdemir, "Kemâlüddîn el-Fârisî'nin Gökkuşağı Açıklaması,", *DTCFD*, XXXIII (1990), pp. 477-492.

210 Sabra, "The 'Commentary'", pp. 122+125.

211 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 3, p. 165.



A drawing representing the formation of a rainbow in a raindrop in the author's autograph copy of Tanqih al-Manāzir by Kamāladdīn al-Fārisī. This manuscript which bears record of Taqiyaddīn ownership, is one of the most important manuscripts in the history of Islamic science. Courtesy of Qatar National Library

IBN AL-HAIṮAM'S

51 MOON OBSERVATION INSTRUMENT

The most significant investigations on the nature of the Moon in classical Islamic civilization were made by the famous scholar Ibn al-Haiṯam. Ibn al-Haiṯam discussed his questions about the Moon and his investigations in two separate treatises titled *On the Light of the Moon* and *On the Nature of Spots on the Surface of the Moon.*[212]

In his treatise *On the Light of the Moon* (*Maqāla fī Ḍauʾ al-Qamar*), Ibn al-Haiṯam wanted to prove that the Moon acts as a self-luminous body in the sense that every part of it, when it receives light from the sun, emits light rays in all directions, and thus differs fundamentally from reflecting, transparent and luminous objects that only allow light to pass through. In this treatise, he also describes in detail the instrument he invented to observe the moonlight and to prove some properties of this light.[213]

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212 Both treatises have been translated into German: Karl Kohl, Über das Licht des Mondes, eine Untersuchung von Ibn al-*Haitam*, Sitzungsberichte der Physikalische-Medizinischen Sozietät in Erlangen, pp. 58-59, 1926-1927, pp. 305-398; Carl Schoy, *Abhandlung des Schaichs ibn Ali al-Hasan ibn al-Hasan ibn al-Haitham: Über die Natur der Spuren* (*Flecken*)*, die man auf der Oberfläche des Mondes sieht*, translated from German: C. Schoy, vii-viii, Heinz Lafaire, Hannover 1925.

213 Sezgin*, İslam'da Bilim ve Teknik*, Vol. 3, pp. 174-177. For a detailed analysis of this instrument, see: M. Schramm, Ibn al-Haytham´s Weg zur Physik, Boethius, Wiesbaden, 1963, pp. 70-87 and 130-189.

IBN AL-HAIṮAM'S

52 EXPERIMENT PROVING THAT THE LIGHT RAYS OF THE DAWN ARE IN A STRAIGHT LINE

In the third chapter of the first book of *Kitāb al-Manāẓir* titled *Investigation on the Properties and Diffusion of Lights,* one of the topics that Ibn al-Haiṯam takes up is whether light rays of the early morning come from the atmosphere in a straight line.[214]

To demonstrate this, he describes an experiment where he instructs the following: in a structure consisting of two adjacent rooms built on the east-west line, a cone-shaped hole should be drilled in the upper part of the east-facing outer wall and a second hole must be drilled on the wall in the middle to follow a line running straight from the first hole in the upper right corner of the structure to the lower left corner of the building in the second room.

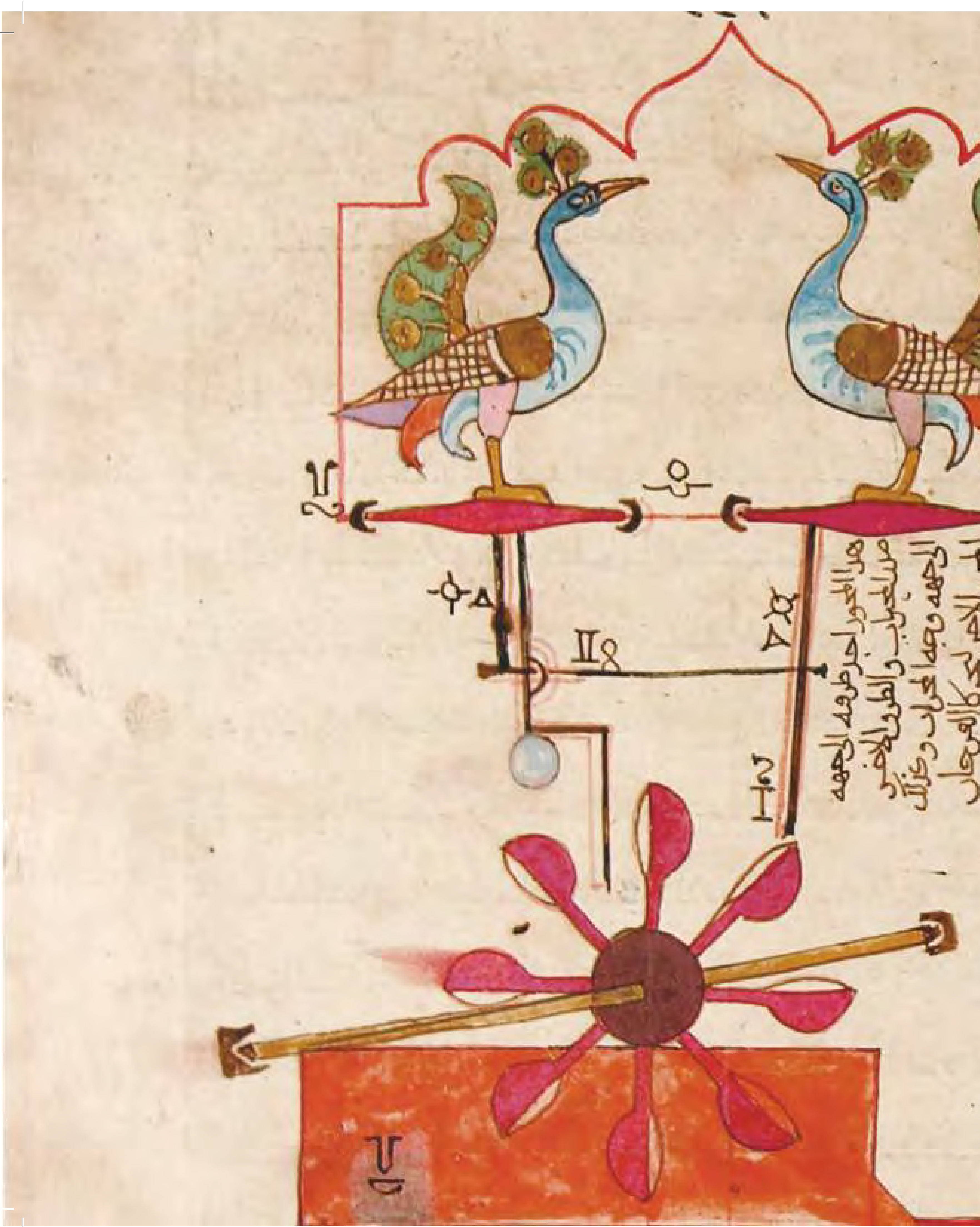
Ibn al-Haiṯam states that once this structure is prepared for the experiment, the person who will do the experiment should enter the building before sun rise and waits for the light. Although the sun will still be below dawn, since a light beam will fall diagonally down from the hole in the east wall of the building in the west direction, it proves that the light will come from the atmosphere and proceed straight.

In his conclusion about this experiment, Ibn al-Haiṯam writes:

"Therefore, this experiment has clearly proven that some light comes from the atmosphere illuminated by the morning light to opposite places and proceeds in straight lines and that the daylight emanating to the Earth before sunrise and after sunset is a light emitted from the atmosphere illuminated by the Sunlight opposite the Earth's surface. If the experimenter examines the luminous atmosphere in the same way for the rest of the day, he will see light emanating from it in straight lines."[215]

214 A. I. Sabra, *The Optics of Ibn al-Haytham: Books I-III.* The Warburg Institute, London 1989, pp. 23-25. Sezgin *, İslam'da Bilim ve Teknik*, Vol. 3, pp. 174-177.

215 Sabra, *The Optics of Ibn al-Haytham*, p. 25, no: 34.



Technology

BY AL-ḪĀZINĪ

“BALANCE OF WISDOM"

53

Among the scholars, flourished in the city of Marw, Abu' l-Fatḥ ʿAbd al-Raḥmān al-Manṣūr al-Ḫāzinī was an emancipated slave of Byzantine origin of Abu'l Husayn' Alī b. Muhammad al-Ḫāzin al-Marwazī. He was known as "al-Ḫāzinī" because his master was the Ḫāzindār, treasurer of the court, at Marw Palace, and he received an excellent education from his master.[7]

Apart from his works on astronomy, al-Ḫāzinī's one of the most important contributions to the history of science is his work on hydrostatic balance titled *"Kitāb Mīzān al-Ḥikmah"*, which was composed for Sanğar, Sultan of the Great Seldjuqs.[8] This book is regarded as the most significant work on the science of balance in the history of Islamic science.
The most innovative chapters in al-Ḫāzinī's work, which consists of eight treatises heavily influenced by the works of Archimedes, Euclid, Birūnī, Rāzī and Omar Ḫayyam, are the fifth and sixth treatises. In these treatises he describes the construction and use of a hydrostatic balance called the "Mīzān al-Ḥikmah" which translates as "The Balance of Wisdom” and which also inspired the title of the work.

This balance is an improved version of another balance with the same name invented by Abū Ḥātim al-Muẓaffar al-Isfazārī, who is one of the teachers of al-Kḫāzinī. According to sources, al-Isfazārī developed a precision balance for Sultan Sanğar that could detect whether metal or precious stones were fake or real, and he called this invention "Mīzān al-Ḥikmah (Balance of Wisdom)". The Sultan's treasurer had this balance destroyed out of fear, and al- Isfazārī "died of sorrow" upon hearing this.[9] It is likely that al-Ḫāzinī named this balance after his teacher since he built it in remembrance of him.

The balance is 2 meters high and has a multi-wire hanger and a precision pointer. The balance has five scalepans in the form of hemispheres for different operations and measurements.[10] Apart from standard weighing processes, the balance could be used for many commercial transactions such as determining the specific gravity, determining the ratio of the other element in binary metal alloys if one of the elements was known, and currency converting between dirham and dinar.[11] Al-Ḫāzinī claimed that the precision of the balance was 60.000 to one, and, for example, could detect a difference of 0.075 grams in a 4.5 kg object.[12] Recently, this balance was remanufactured by two Iranian researchers according to the instructions given and examined in detail, and as a result of the experiments, it was determined that al-Ḫāzinī's claims about the precision of his balance were correct, and it was concluded that the balance was extraordinarily sensitive for that period.[13] The model we have is manufactured according to al-Kḫāzinī's descriptions in his work.[14]

7 For an overview of al-Ḫāzinī's life and works, see: Robert E. Hall, “al-Khāzinī”, Dictionary of Scientific Biography, vol. VII (1973), p. 335-351; J. Vernet, “al-Khazinī”, Encyclopaedia of İslam: Second Edition, vol. IV, p. 1186; Sadettin Ökten, “Abdurraman el-Hâzini”, DİA, vol. 1, p. 164-165.
8 The theoretical part of this work was realized within the scope of a doctoral thesis and was published in Tunisia with its authenticated text and French translation. See: Faïza Laridhi Bancel, *Kitāb Mīzān al-Ḥikma de 'Abd al-Raḥmān al-Khāzinī*, l'Academie Tunisienne des Sciences, des Lettres et des Arts, Beit al-Hikma, 2008
9 Robert E. Hall, “al-Khāzinī”, *Dictionary of Scientific Biography*, vol. VII (1973), p. 339
10 Robert E. Hall, “al-Khāzinī”, p. 346
11 Sezgin, *İslam'da Bilim ve Teknik*, vol. 5, p. 6
12 Robert E. Hall, “al-Khāzinī”, p. 346
13 Y. Yassi & Reza Yassi, “Al-Khazini's Balance of Wisdom: A Masterpiece of Medieval Engineering”. *Nuncius* (2020), 1-18.
14 Sezgin, *İslam'da Bilim ve Teknik*, vol. 5, p. 6

TAQĪYADDĪN'S SIX-PISTON

54 WATER PUMP

The famous Ottoman astronomer and inventor Taqīyaddīn Ibn Marʿūf wrote a work titled *aṭ-Ṭuruq as-Sanīya fī l-Ālāt ar-Rūḥānīya* (*Excellent Methods in Making Extraordinary Tools*) on mechanical tools in 1551 AD, when he was only 25 years old.[216] The most important work written on mechanical instruments in the Ottoman period, it has four copies in the world, in Kandilli Observatory, Dublin and Cairo. The copy in the Kandilli Observatory is one of the most valuable documents that have survived to the present day in terms of the history of Islamic science, due to the fact that it the author's autograph copy.[217]

One of the most original inventions he describes in this work is the water pump with six pistons. Although this pump has a monolithic body, it has 6 pistons.

Here's how the pump works: The water wheel, which moves with the flow of the water, enables the hexagonal camshaft to rotate. 6 teeth located on each face of the camshaft push down the 6 seesaws in line with each other, and a piston connected to the other end of the seesaw with a weight on the top rises. With the sucking effect of the rising piston, the entry valve lid at the bottom opens and the reservoir is filled with water. When the seesaw on the side of the piston descends again, the entry valve of the reservoir closes, preventing the water from flowing back.

At the same time, the piston, which goes down with the effect of the weight on top of it, pushes the water in the reservoir upwards, this time opening the exit valve lid above and allowing the water to flow upwards. When the piston starts to rise again, the exit valve prevents the water from flowing back.

Our model was built according to the description and drawings in the work.[218]

The autograph copy of this work is registered in Kandilli Observatory Library with no. 96. The work was first studied by the historian of Islamic science Ahmad Y. al-Hassan and published together with a facsimile. See: Ahmad Y. al-Hassan, *Taqi al-Din and Arabic Mechanical Engineering*, Chester Beatty Library No. registered at 5232 with the facsimile of the manuscript, Institute for the History of Arabic Science, University of Aleppo, 1976, pp. 38-42. For an annotated Turkish translation to be published soon, see: Atilla Bir, Mustafa Kaçar & Âdem Akın, *16. Yüzyıl Osmanlı Astronomu Takiyüddin er-Râsıd´ın Et-Turuku´s-Seniyye fi´l-Âlât´r-Ruhâniye* (*Olağanüstü Aletlerin Yapımında Şahane Yöntemler*) *Adlı Eserinin Çeviri ve Yorumu*, Türkiye Bilimler Akademisi İstanbul, (forthcoming). I am indebted to the authors for allowing me to use this work before it is published. 216

217 For detailed information about the Kandilli manuscript, see: Günay Kut & Fatma Büyükkarcı Yılmaz, *Kandilli Rasathanesi El Yazmaları*, Boğaziçi University Press, Istanbul 2002, pp. 243, 245.

218 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 5, p. 28-29.

TAQĪYADDĪN'S STEAM DRIVEN

55 APPARATUS FOR TURNING ROAST MEAT

The famous Ottoman astronomer and inventor Taqīyaddīn Ibn Marʿūf wrote a work titled *aṭ-Ṭuruq as-Sanīya fī l-Ālāt ar-Rūḥānīya* (*Excellent Methods in Making Extraordinary Tools*) on mechanical tools in 1551, when he was only 25 years old. The most important work written on mechanical instruments in the Ottoman period, it has four copies in the world, in Kandilli Observatory, Dublin and Cairo.[219] The copy in the Kandilli Observatory is one of the most valuable documents that have survived to the present day in terms of the history of Islamic science, due to the fact that it is an autograph copy.[220]

The work written in six parts, consists of the following headings: 1) Water clocks, 2) Levers, 3) Water risers, 4) Fountains and continuously playing flutes and drums, 5) Agricultural irrigation equipment, 6) Automatic roasting spit machines.

One of the most original inventions in Taqīyaddīn's work is the steam driven roasting spit machine. In this machine, the water heating in a metal boiler runs from the end of the pipe coming out of the vessel with pressure, and the power it applies to a propeller mounted on the top of the vertical roasting meat makes the roasting spit rotate. Taqīyaddīn also reports that he made another roasting spit tool powered by air. This steam engine by Taqīyaddīn is the first device in history to use steam power for a practical application.[221]

Our model was built according to the description and drawings in the work.[222]

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219 This work was first studied by the late historian of Islamic science Ahmad Y. al-Hassan and published with a facsimile. See: Ahmad Y. al-Hassan, *Taqi al-Din and Arabic Mechanical Engineering*, with the facsimile of the manuscript registered in Chester Beatty Library No. 5232, Institute for the History of Arabic Science, University of Aleppo, 1976, pp. 38-42. For an annotated Turkish translation of the work to be published soon, see: Atilla Bir, Mustafa Kaçar and Adem Akın, *16. Yüzyıl Osmanlı Astronomu Takiyüddin er-Râsıd'*ın *Et-Turuku's-Seniyye fi'l-Âlât'r-Ruhâniye* (*Olağanüstü Aletlerin Yapımında Şahane Yöntemler*) *Adlı Eserinin Çeviri ve Yorumu*, Türkiye Bilimler Akademisi, Istanbul, (forthcoming). I am indebted to the authors for allowing me to use this work before it is published.

220 Kandilli Observatory Library no. 96. For detailed information on the manuscript, see: Günay Kut & Fatma Büyükkarcı Yılmaz, *Kandilli Rasathanesi El Yazmaları*, Boğaziçi University Press, Istanbul 2002, pp. 243, 245.

221 On the official website of Ahmad al-Hassan, the historian of Islamic Sciences, a brief note on the historical significance of this roasting spit tool and its Arabic text, as well as its English translation, are available. See: http://www.history-science-technology.com/notes/notes1.html. Last visited: 18-3-2019.

222 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 5, p. 37.

DEVELOPED BY TAQĪYADDĪN FOR LIFTING LIFTING HEAVY OBJECTS:

56 GEAR WHEEL LEVER

One of the tools that the famous Ottoman inventor and scientist Taqīyaddīn described and drew in his work titled *aṭ-Ṭuruq as-Sanīya fī l-Ālāt ar-Rūḥānīya* (*Excellent Methods in Making Extraordinary Tools*) on mechanical inventions is a gear wheel lever that serves to lift heavy objects with relatively little force.[223] The system consists of 3 equivalent gear pairs and a lever placed in a rectangular box.

Known since antiquity, and first mentioned in *Mechanica* and *Dioptra* by Heron of Alexandria (1st century AD), this type of lever was known as "Barulkos" at that time. Unfortunately, the Greek original of the *Mechanica* by Heron of Alexandria has not survived to our day, while the Arabic translation by Qusṭā b. Lūqā, known with the title *On Lifting Heavy Objects,* has survived.[224] The Barulkos mechanism is also discussed in book 8 of Pappus's work known as *The Mathematical Collection.* This work was translated into Arabic in the 9th century as *Introduction to the Science of Mechanics* (*Madḫal fī el- Ḥiyāl*).[225]

Taqīyaddīn describes the lever he designed in the second part of his work, as "a tool that pulls a weight of 31 weighbridges (1750 kg) when *5 raṭl* (9 kg) of force is applied to it".[226] Taqīyaddīn's work is of great importance as it is the only example in the Islamic mechanical tradition where a gear wheel mechanism is used to lift heavy loads.[227]

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223 The autograph copy of this work is registered in Kandilli Observatory Library with no. 96. For an annotated Turkish translation of the work to be published soon, see: Atilla Bir, Mustafa Kaçar and Adem Akın, *16. Yüzyıl Osmanlı Astronomu Takiyüddin er-Râsıd'ın Et-Turuku's-Seniyye fi'l-Âlât'r-Ruhâniye* (*Olağanüstü Aletlerin Yapımında Şahane Yöntemler*) *Adlı Eserinin Çeviri ve Yorumu*, Türkiye Bilimler Akademisi, İstanbul, (forthcoming). I am indebted to the authors for allowing me to use this work before it is published.

224 4 Arabic copies of this work have survived to the present day. For a current critical edition, English translation and analysis of the work, see: Guiseppina Ferriello, Maurizio Gatto and Romano Gatto, *The Baroulkos and the Mechanics of Heron*, Leo S. Olshki, Firenze, 2016.

225 The following are the extant copies: Hagia Sophia 3624 and Topkapı Palace Museum Ahnet III, 3457 in the collection in the Süleymaniye Library. The Topkapı copy of the work is the autograph copy of the famous Iranian mathematician al-Sijzi and is a very valuable copy. For information about this Arabic translation, see: David E.P. Jackson, *The Arabic Version of the Mathematical Collection of Pappus Alexandrinus*, Book VIII, University of Cambridge 1970 (unpublished doctoral dissertation). See also: David E. P. Jackson, Scholarship in Abbasid Baghdad with Special Reference to Greek Mechanics in Arabic, *Quaderni di Studi Arabi*, 1987-1988, Vol. 5/6, pp. 369-390. A critical edition and translation of this work is being prepared by the Islamic science historian Elaheh Kheirandish.

226 Atilla Bir, Mustafa Kaçar and Adem Akın, *16. Yüzyıl Osmanlı Astronomu*, Part Two (to be published).

227 We see examples of gear wheels in al-Ǧazarī and al-Bīrūnī, but they are not purposed to lift heavy loads.

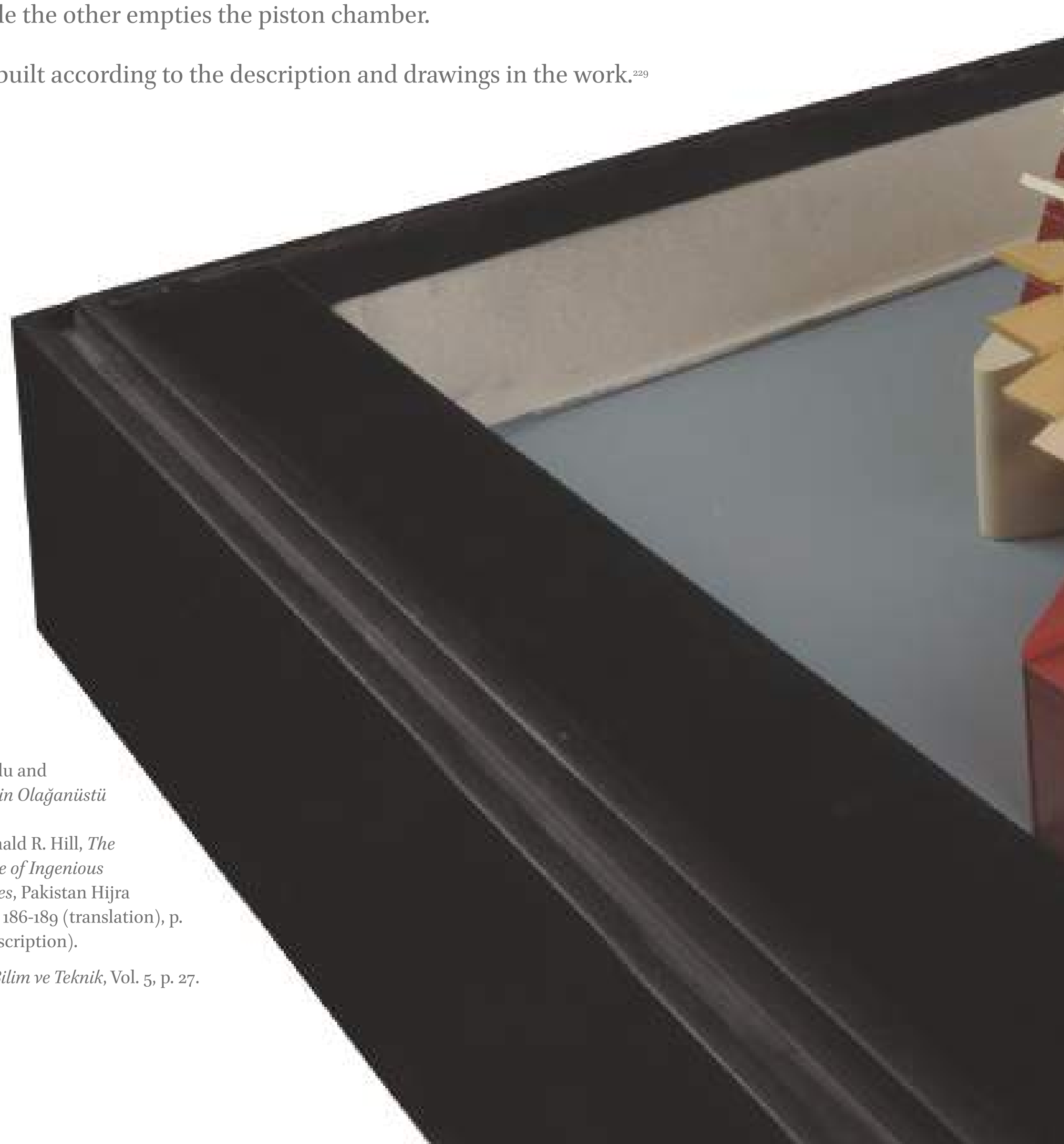
AL-ĞAZARĪ'S

57 TWO-PISTON WATER PUMP

The ruler he worked for asked Abu l-ʿIzz Ibn ar-Razzāz al-Ğazarī, who was working in the Artuqid Palace at the beginning of the 13th century, to write a work so that the tools he produced for him would not be lost, and to describe the construction of the tools he made in this work. Al-Ğazarī described the making of about 50 tools in his *al-Ğāmiʿ Bain al-*ʿİlm *wa-l-*ʿAmal *an-Nāfiʿ fī Ṣināʿat al-Ḥiyal*, which he wrote for this purpose. The work describes the construction of water and candle clocks, lock mechanisms, automata for entertainment, fountains and other mechanisms related to water.

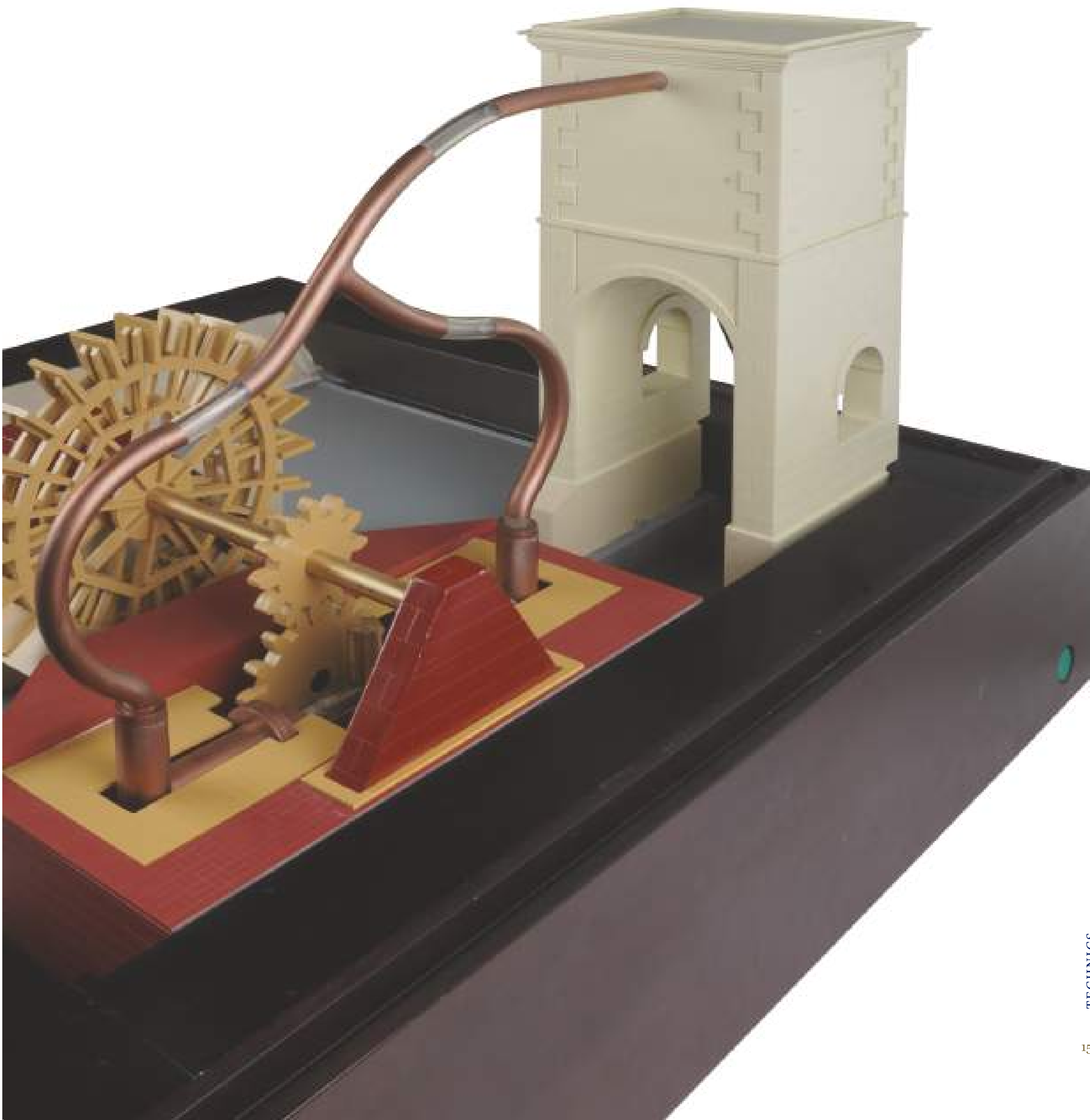
One of al-Ğazarī's original inventions is the 2-piston water pump which he describes under the title "Fifth form of the fifth type: a tool that lifts water from a river with the help of a chamber up to 20 ziras."[228] The most important feature of this pump is the linear forward and reverse rotation of a circular motion. The use of two pistons ensures a continuous pumping of water. One piston sucks water while the other empties the piston chamber.

Our model was built according to the description and drawings in the work.[229]



228 Fazlıoğlu, Fazlıoğlu and Çalışkan, *Cezeri'nin Olağanüstü Makinaları*, Vol. II, p. 224-236; Donald R. Hill, *The Book of Knowledge of Ingenious Mechanical Devices*, Pakistan Hijra Council, 1988, pp. 186-189 (translation), p. 266 (technical description).

229 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 5, p. 27.



58

AL-ǦAZARĪ'S

COMBINATION LOCK

al-Ǧazarī describes the construction of a combination lock mechanism as the third figure in the sixth chapter of his work titled *Reconciling Knowledge and Practice in the Science of Mechanics.*[230] From what al-Ǧazari describes at the beginning of the chapter, it becomes clear such locks were widely known in the Islamic world: "The old masters made locks that unlocked and locked with letters; among them, there are those that lock with 4 letters on 4 circles, those that lock with 2 letters on 2 circles, and those that lock with 6 letters on 6 circles. I built a chest and placed a lock on its lid, which I will describe now."[231] Unlike the other models al-Ǧazari mentions, the model he has produced has four knobs made up of 3 interlocking combination rings for each knob. Therefore, considering that there are four knobs on the mechanism and 16 letters are used in each knob, it would be impossible to crack the code since there would be 16^{12} or 2^{48} . i.e 281 trillion combinations in al-Ǧazarī's combination lock[232] Composed of multiple parts, this instrument is truly an engineering marvel for its time.

The model we have was built according to the description and drawings in the work.[233]

230 Fazlıoğlu, Fazlıoğlu and Çalışkan, *Cezeri'nin Olağanüstü Makinaları*, Vol. II, pp. 259-268, 307-308, 315-316; Hill, *The Book of Knowledge,* pp. 199-201 (translation), p. 274 (technical description).

231 Fazlıoğlu, Fazlıoğlu and Çalışkan, *Cezeri'nin Olağanüstü Makinaları*, p. 259.

232 Fazlıoğlu, Fazlıoğlu and Çalışkan, *Cezeri'nin Olağanüstü Makinaları*, Vol. 2 H. 259 +307.

233 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 5, pp. 56-58.

59

AL-ĞAZARĪ'S FOUR-BOLT

DOOR LOCK MECHANISM

al-Ğazarī describes the construction of a four-bolt door-lock mechanism as the fourth figure in the sixth chapter of his work titled *Reconciling Knowledge and Practice in the Science of Mechanics.*[234] This four-bolt door lock mechanism, which he defines as "four locks on a single door", allows four bolts mounted on the back of a door at an angle of ninety degrees to each other, moving at the same time and locking a door securely.

The movement of the bolts, which join in a square shape in the middle of the door, is not hindered by the fact that the two vertical bolts that lock the upper and lower parts of the door are located higher than the two horizontal bolts that lock the sides. The mechanism that enables all four bolts to move at the same time is the gear mechanism, which is now called "rack bolt" (French: crémaillère). Since the gear wheel located in the middle of the door and rotating with the key is in contact with the gears on all four bolts at the same time, the bolts move forward or backward at the same time with the rotation of the wheel.

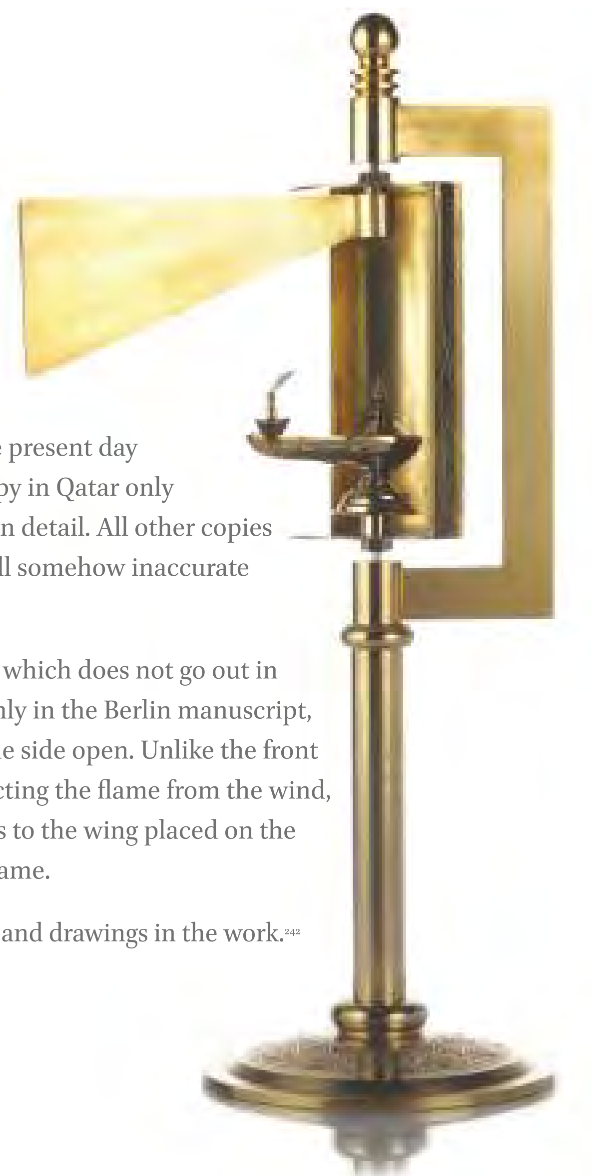
Our model was built according to the description and drawings in the work.[235]

234 Fazlıoğlu, Fazlıoğlu and Çalışkan, *Cezeri'nin Olağanüstü Makinaları*, pp. 269-276 (translation and technical explanation), pp. 308-309 (summary explanation), p. 317 (photo of the reconstruction); Hill, *The Book of Knowledge,* pp. 202-203 (translation), p. 270 (technical description).

235 Sezgin *, İslam'da Bilim ve Teknik*, Vol. 5, p. 59.

60 AN OIL LAMP THAT THAT WILL NOT BE BLOWN OUT BY THE WIND

BANŪ MŪSĀ BROTHERS



The Banū Mūsā brothers, who worked in Bait al-ḥikma in Baghdad in the 9th century, wrote works on mathematics, astronomy and many other fields. In their *Kitāb al-Ḥiyal* about mechanical inventions, they describe a hundred different inventions, some of them practical, along with many entertainment automata.[239]

Four copies of the work that have survived to the present day are in Topkapı, Berlin, Vatican and Qatar. The copy in Qatar only appeared recently and has not yet been studied in detail. All other copies used for the critical edition and translation are all somehow inaccurate and incomplete.[240]

One of these practical inventions is the oil lamp, which does not go out in strong winds.[241] This lamp, which is mentioned only in the Berlin manuscript, is made in the form of a vertical cylinder with one side open. Unlike the front part of the cylinder, which acts as a casing protecting the flame from the wind, it turns towards the direction of the wind, thanks to the wing placed on the side of the flame, and becomes a shield for the flame.

Our model was built according to the description and drawings in the work.[242]

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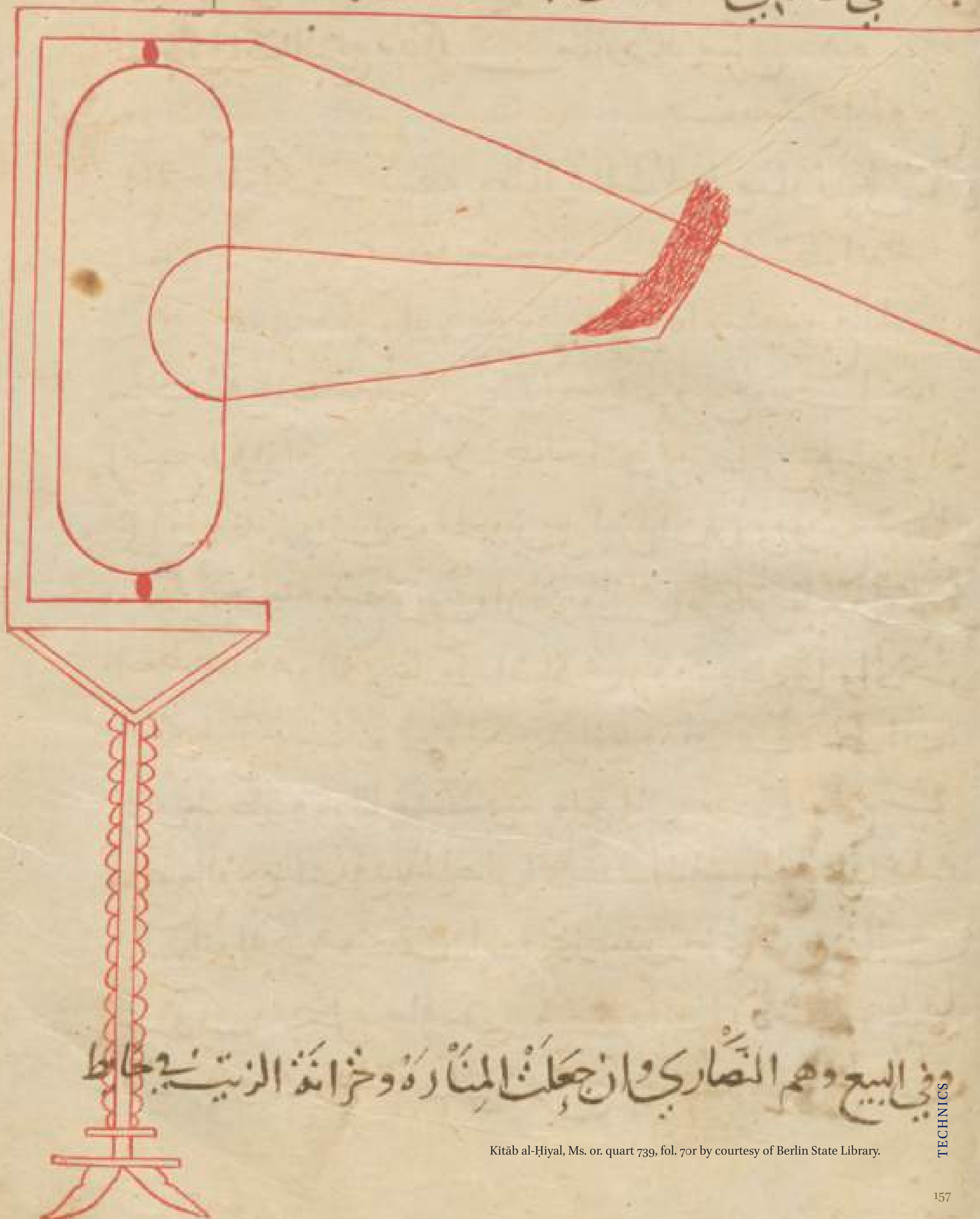
239 Critical edition: Ahmad Y. al-Hasan, *Kitab Al-Hiyal: The Book of Ingenious Devices,* Jamiat Halab, Mahad al-Turath al-Ilmi al-Arabi, Aleppo 1981, English translation: Donald R. Hill, *The Book of Ingenious Devices*, Dordrecht 1979. Reprint: Donald R. Hill, *The Book of Ingenious Devices*, Pakistan Hijra Council, 1986.

240 In his English translation he prepared by comparing the three manuscripts, Donald Hill argues that the instruments numbered from 1 to 87 are definitely by Banū Mūsā, while instruments from 88-93 are probably by Banū Mūsā. He says that of the remaining tools numbered from 95 to 100, number 94 is definitely not by Banū Mūsā, while the other instruments cannot be attributed to anyone. See: Donald R. Hill, *The Book of Ingenious Devices*, Pakistan Hijra Council, 1986, p. 13.

241 Critical edition: Ahmad Y. al-Hasan. *Kitab Al-Hiyal: The Book of Ingenious Devices*. Jamiat Halab, Mahad al-Turath al-Ilmi al-Arabi, Aleppo 1981, pp. 372-373; English translation: Donald R. Hill: *The Book of Ingenious Devices*, Dordrecht 1979, pp. 238-239.

242 Sezgin *, İslam'da Bilim ve Teknik*, Vol. 5, p. 45.



Kitāb al-Ḥiyal, Ms. or. quart 739, fol. 70r by courtesy of Berlin State Library.

61

APPARATUS FOR REMOVING OBJECTS FROM THE WATER

GRAB DREDGER

Another invention mentioned in the *Kitāb al-Ḥiyal* is the apparatus for lifting objects from water.[243]

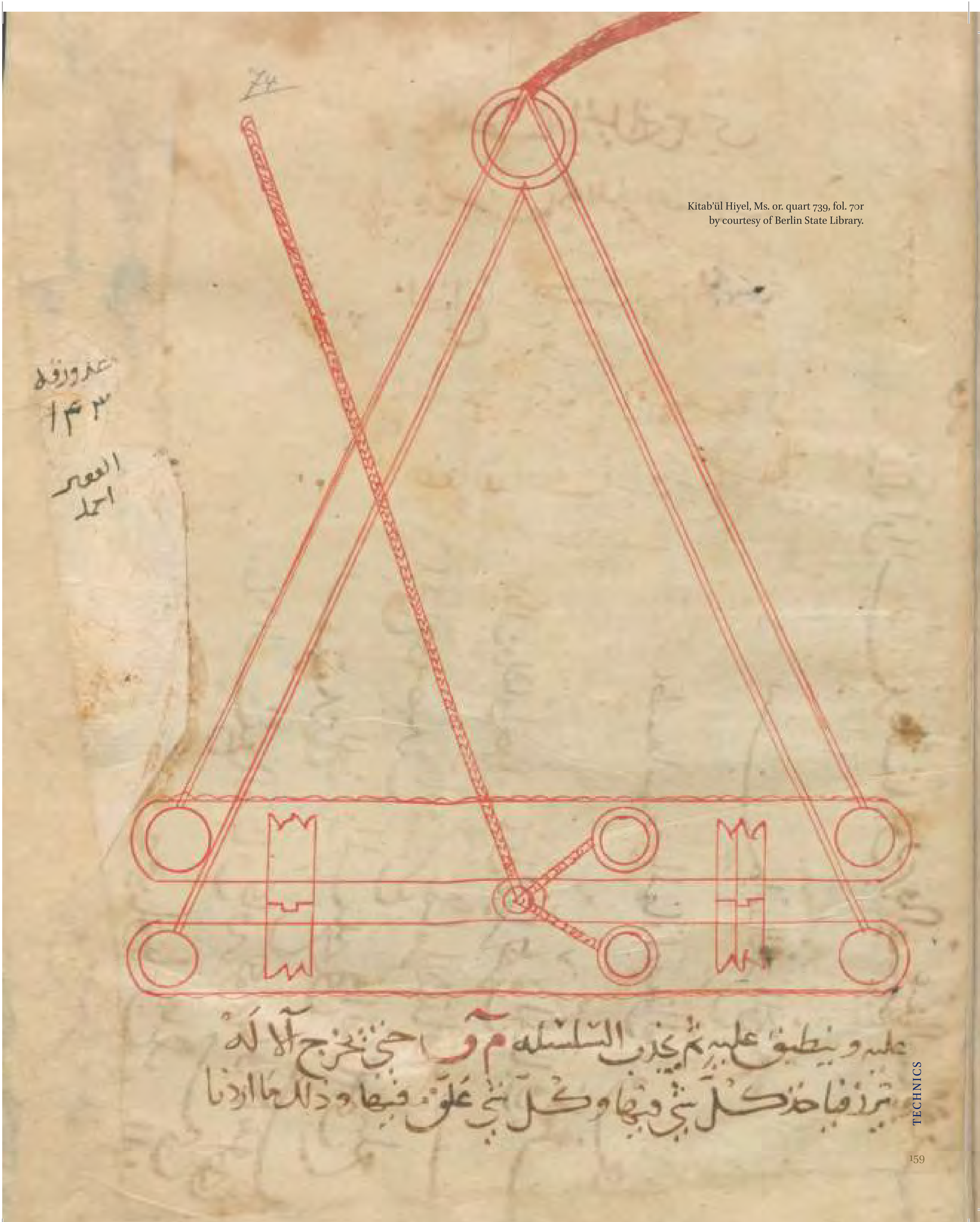
In the Berlin copy, this instrument is described as follows: "We want to show how to make an instrument with which a person, when he lets it down, can take out material (ǧauhar) from the sea and those objects that have fallen into wells and those that have sunk into rivers and seas. For this purpose we construct the two halves … and …. of a [hollow] cylinder of copper, which are equal to one another; if one half exceeds the other a little in weight then that is better for the present purpose so that one half may take the other one into it (devour it) and [the second one] may enter into the first one a little."[244]

Our model was built according to the description and drawings in the work.[245]

243 Critical edition: Ahmad Y. al-Hasan, *Kitab Al-Hiyal: The Book of Ingenious Devices,* Jamiat Halab, Mahad al-Turath al-Ilmi al-Arabi, Aleppo 1981, pp. 376-379; English translation. Donald R. Hill: *The Book of Ingenious Devices*, Dordrecht 1979, p. 242-243.

244 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 5, p. 43.

245 Sezgin *, İslam'da Bilim ve Teknik*, Vol. 5, p. 43.



Kitab'ül Hiyel, Ms. or. quart 739, fol. 70r
by courtesy of Berlin State Library.

Chemistry

62 ALEMBIC

Distillation is one of the oldest separation methods used by humans. The oldest distillation instruments were found at Tepe Gawra in the northeast of Ancient Mesopotamia in archeological excavations.[246] These ceramic distillation instruments, called channel rim devices, were dated to 3500 BC.[247] Again, texts mentioning the use of the said ceramic distillation devices were found on cuneiform tablets in archaeological excavations.[248] One of these texts (some in Istanbul), which are mostly about perfume production and dated to 1200 BC, states, "*This* (*recipe*) *is about the preparation of flowers, oils and calamus* (*sweet sedge*) *for producing perfume for the King based on the recipe given by the* (*female*) *perfumer Tappûti-Bêlatêkallim."*
Thus, thanks to this text, we learn that the oldest chemist with a known name was a woman and her name was Tappûti-Bêlatêkallim.[249] Ceramic devices similar to those found at Tepe Gawra were later found in Bronze Age excavations in Turkey, Cyprus, Sardinia and Slovakia.[250] Some studies have revealed that there are Babylonian-style recipes as well as chemical methods and instruments inherited from Ancient Greece in early Islamic chemistry manuscripts.[251] The famous historian of chemistry Martin Levey, who studied the link between Babylon and the Islamic chemistry tradition, thinks that the recommendation to repeat the distillation process dozens of times in the recipes in Islamic chemistry works is inherited from the Babylonian period rather than being a requirement.[252] Accoring to Levey, distillation apparatuses in the golden age of Islamic chemistry were too advanced to require such a repetition.[253]

The type of distillation apparatus in question was widely used in the Islamic chemistry tradition; it is made of glass instead of ceramic and consists of two parts. The bottom piece is called *ḳarʿ* (as it looks like a gourd. Latin: cucurbit) and the upper part is called *al-inbīq ḏāt al-ḫatm* (alembic with beak, Latin: alembic).[254] The reason why it is called beaked is the pipe in the upper part that resembles a bird's beak. The glass retort attached to the end of this pipe, which helps to channel the distilled liquid outside, was called *al-qābila,* that is, the "receptacle."

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246 On Tepe Gawra and the excavations and findings there, see: Yüksel Arslantaş, "Kuzey Mezopotamya´da Bir Kavşak Noktası: Tepe Gawra", *Fırat Üniversitesi Orta Doğu Araştırmaları Dergisi*, Vol. 8 (2013), issue 2. For ceramic distillation apparatuses found at Tepe Gawra, see: Martin Levey, "Evidences of Ancient Distillation, Sublimation and Extraction in Mesopotamia", *Centaurus* c. 4 (1955), issue 1, pp. 23-33; Martin Levey, "The Earliest Stages of the Evolution Still", Isıs, Vol. 51 (1960), issue 1, pp. 31-34.

247 Levey, "Evidences of," pp. 23-26; Levey, "The Earliest Stages", pp. 32-33.

248 Martin Levey, "A Group of Akkadian Texts on Perfumery", *Chmyia*, Vol. 6 (1960), pp. 11-19.

249 Levey, "A Group of Akkadian", p. 16. For a more comprehensive study, including the original texts, see: E. Ebeling, *Perfumerezepte und Kultische Texte aus Assur*, Pontifical Biblical Institute, Rome 1950.

250 Among these finds, Cyprus is particularly interesting because not only distillers but a complete perfume production facility were found here. Today, this area has been transformed into a theme park in the form of a living museum. For website see: http://www.perfumecypark.org

251 Martin Levey, "Early Muslim Chemistry: Its Debt to Ancient Babylonia", *Chymia* c. 6 (1960), pp. 20-26.

252 Levey, "Early Muslim Chemistry", p. 24.

253 Levey, "Early Muslim Chemistry", pp. 24-25.

254 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 4, p. 126.

The word "imbik" (alembic in Turkish) has been imported into Turkish from Arabic and originally comes from the Greek word "ambix". As the word was transferred to the West from the Islamic world, "*al-inbīq*" was Latinized as "alembic". This type of two-piece glass distillation apparatus appeared for the first time in the late Greek sources.[255]

In this period, there were also a series of innovations in distillation methods. For example, today the distillation method known as (Au) Bain-Marie (French, Latin: Balneum Mariae), that is, "Mary's bath", was named after an alchemist known as Mary the Jewess in the West, and Māriye in Islamic sources, who is believed to have lived in the first century.[256] Although her work has not survived to the present day, when the quotations from Māriye's works made by another important Greek alchemist known in the Islamic tradition, Zosimos (3rd-4th century AD) are examined, the extent of her contributions to chemistry become evident.

These inventions include temperature-controlled distillation apparatuses where the retort was placed over manure, ash or boiling water.[257] Although not used in the context of distillation, placing a bowl over a container containing water and heating it to melt something in the kitchen is still called the bain-marie method today.

Alembic with beak and *ḳarʿ*, which are considered among the basic chemistry tools in Islamic chemistry texts and generally used for the distillation of liquids, were widely used in the Islamic world.[258]

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255 For example, see: Paris National Library Gr. 2387, fol. 81. For an online copy of the manuscript, see: https://gallica.bnf.fr/ark:/12148/btv1b10723905w/f88.item. For an overview of the history and sources of chemistry in the Greek period, see: F. Sherwood Taylor, "A Survey of Greek Alchemy," *The Journal of Hellenistic Studies*, Vol. 50, chapter 1 (1930), pp. 109-139.

256 For example, in the tenth *article of* Ibn an-Nadīm's famous bibliographical work named *al-Fihrist,* in which he introduces the ancient chemists/alchemists, her name is mentioned as "Māriye" and two books by her are mentioned with the titles *Kitāb al-Māriye al-Kibtiyye Me'a al-Hukemā, Hīne* İcteme'ā *al-Kibriye* Māriye and Kitāb al-Kibriye. See: Muḥammad ibn Isḥāq an-Nadīm, *al-Fihrist*, pp. 887-889. For Māriye's life and works, see: Naomi Janowitz, *Magic in the Roman World: Pagans, Jews and Christians* (*Religion in the First Christian Centuries*), Routledge, New York & London 2001, pp. 59-69.

257 F. S. Taylor, "A Survey of Greek Alchemy," *The Journal of Hellenic Studies*, Vol. 50 (1930), issue: 1, p. 116.

258 For the list, names and definitions of chemical instruments in Islamic chemistry texts, see: Eilhard Wiedemann, "Über chemische apparate bei den Arabern" in: *Beitrage aus der Geschichte der Chemie*, Georg W. A. Kahlbaum, Leipzig and Vienna 1909, pp. 234-252.

AD-DIMAŠQĪ'S (D. 727/1327) INDUSTRIAL SIZE APPARATUS FROM DAMASCUS

63 FOR EXTRACTING ROSE WATER

Distillation, one of the important techniques developed in the field of chemistry in the history of Islamic science, was widely used in many different fields, not only scientifically but also industrially. For example, aromatic waters and oils produced through distillation such as distilled vinegar (acetic acid), distilled wine (alcohol), rose water and rose oil were the major areas in which the distillation technique was used on an industrial scale.[259]

Among aromatic waters produced industrially in the medieval Islamic world, rose water was particularly popular. Rose water and oil, which are among major symbols of Islamic civilization, were used not only in cosmetics but also in medicine and food production.[260] Rose water was even exported to Europe.[261]

BNF Ms. Arabe 2187. Courtesy of the National Library of France

The Damascus region, famous for its rose in the Islamic world, was best known for its rose water production. In his *Nuḫbat ad-Dahr fī* 'Aǧā'ib *al-Barr wa-l-Baḥr*, the cosmographer Abū 'Abdallāh Šamsaddīn Muḥammad b. Ibrāhīm b. Abī Ṭālib al-Anṣārī aṣ Ṣūfī Šaiḫ ar-Rabwa ad-Dimašqī (d. 727/1327) describes the industrial rose water extraction apparatus he saw in the village of Mizze, near Damascus. According to the description ad-Dimašqi gave, the apparatus was one and a half man tall.[262]

Our model was built according to the description and drawings in the work.[263]

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259 For a general introduction to chemistry in Islamic civilization, see: Mohammed Abdul Mujeeb Khan, "Chemistry and Alchemy", *The Oxford Encyclopedia of Philosophy, Science, and Technology in Islam*, Vol I, pp. 133-140; Ahmad Y. al-Hassan, *Science and Technology in Islam, Part 2: Technology and Applied Sciences,* The Different Aspects of Islamic Culture, Vol. 4, Unesco Publishing, Paris 2001, pp. 41-84; Ahmad Y. al-Hassan, Donald R. Hill, *Islamic Technology: An Illustrated History*, Cambridge University Press, Cambridge 1992, pp. 133-176; Donald R. Hill*, Islamic Science and Engineering*, Edinburgh University Press, 1993, pp. 76-91. For the Turkish translation, see: Donald R. Hill, Atilla Bir (trans.), Mustafa Kaçar (trans.), *Gökyüzü ve Bilim Tarihi: İslam Bilim ve Teknolojisi*, Boyut Yayınları, İstanbul 2010, pp. 60-69; For the history of distillation in Islamic chemistry, see: Jolanda Guardi, "La Distillazzione Car", Gorgias Gambacorta, Jolanda Guardi, et al., *L'arte della distillazione*, Ars Antiqua, 2008 (in Italian). On alcohol and distilled wine, see: Ahmad Y. al-Hassan, *Studies in al-al-Kimya': Critical Issues in Latin and Arabic Alchemy and Chemistry*, Georg Olms Verlag, Hildesheim 2009, pp. 283-298.

260 When some important Islamic cookbooks that have survived to the present day are examined, rose water is seen to be used widely, at least in the palace kitchens. For examples, see: Nawal Nasrallah, *Annals of the Caliph's Kitchen*, Charles Perry, *A Baghdad Cookery Book*, el-Bağdādī, Charles Perry*, Scents and Flavors: A Syrian Cookbook*, New York University Press, New York 2017. Interestingly, rose water distillation techniques are mentioned in some cookbooks in the sections that include the (distillation and coloring) recipes for aromatic waters used in order to leave a pleasant scent in one's hands after washing. For example, see: Charles Perry, *A Syrian Cookbook*, Chapter 10, pp. 262-277.

261 For example, rose water and alcohol were among the products imported to Florence from the Islamic world between 1310 and 1340. See: Robert S. Lopez, Irwing W. Raymond, *Medieval Trade in the Mediterranean: Illustrative Documents*, Columbia University Press 2001, p. 109.

262 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 4, p. 113. See also, ed-Dimeshkī, *Nuḫbet ed-Dehr fī 'Acā'īb wa-l-Bahr*, ed. A. F. Mehren, St. Petersburg 1866, pp. 194-195; A. F. Mehren, *Manuel de la cosmographie du moyen âge,* Kopenhagen 1874, p. 264.

263 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 4, pp. 113-114.

64 ANDALUSIAN PHYSICIAN AZ-ZAHRĀWĪ'S APPARATUS FOR THE DISTILLATION OF ROSE WATER

In chapter 28, paragraph three of his encyclopedic medical work *Kitāb at-Taṣrīf li-man* ʿAǧiza ʿan *at-Taṣnīf,* the Andalusian physician Abu l-Qāsim Ḫalaf b. ʿAbbās az-Zahrāwī (late 4th/10th century) mentions rose water distillation and describes a rosewater distillation apparatus.[264]

Az-Zahrāwī mentions four methods used in rose water distillation: 1. With water and wood fire, 2. With water and coal fire, 3. With wood fire and without water, 4. With coal fire and without water. Az-Zahrāwī explains the construction of the apparatus after stating that the first method is the most common. He divides these methods into two, namely the Iraqi and Andalusian methods. According to Prof. Fuat Sezgin, these two mechanisms are not that different from each other. In the Iraqi method, a large lead vessel (*ṣihrīǧ*) is placed in a large room. The base and sides of this vessel are watertight. This vessel must have a tight lid. As many holes as required by the number and size of the intended retorts (*buṭūn*) must be cut into the lid: fifty, one hundred or two hundred. Then a copper couldron in the form of a bath tub must be provided. This cauldron (as a water reservoir) must be fixed behind the wall and placed above the vessel on the stove. In order not to damage the rose water, the smoke coming out of the oven must be directed upwards. After that, the water must be directed (from the cauldron) into the vessel on the stove. Horned retorts must be placed in the holes and the spaces in between should be sealed well with linen strips. If the retorts are not glass, they can be made from glazed earthenware. The same applies to distillation vessels, into which rose water is dripped.[265]

Our model was built according to the description and drawings in the work.[266]

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264 Sami Khalaf Hamarneh, *A Pharmaceutical View of Abulcasis Al-Zahrāwī in Moorish Spain: with Special Reference to the "Adhān",* EJ Brill, Leiden 1963.

265 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 4, p. 111.

266 Sezgin *, İslam'da Bilim ve Teknik*, Vol. 4, p. 111

65

DESCRIBED BY ABŪ BAKR AR-RĀZĪ

AN ADVANCED ALEMBIC

Kitāb Sirr al-Asrār, penned in the 10th century by Abū Bakr ar-Rāzī, a leading medieval scholar, is one of the most important texts in the history of chemistry.[267] Ar-Rāzī explains in the introduction to his work that he wrote this book as a "guide to the science of chemistry" upon the request of a student he loved very much, and with this work he gave him something that he had not given to any ruler before. He stressed that he wrote a short and concise work by making use of all his other books and explained the indispensable features of chemistry in this work. The book consists of three parts: on substances, chemical equipment and methods. Ar-Rāzī says, "Had my days not been numbered and death not imminent, I would not have toiled to put together the service I wanted to offer for friendship in such a perfect way."[268]

Ar-Rāzī 's words indicate that he wrote this work late in his life. Gail Marlow Taylor, a science historian with 25 years of laboratory experience, has studied this work extensively in recent years and argued that it has all the features of a modern laboratory manual and therefore it can be seen as a pioneer of this genre. Analyzing *Kitāb Sirr al-Asrār* in terms of the criteria that modern laboratory manuals must comply with, Taylor occasionally compares the work to modern manuals and reveals that it is compatible with these criteria.[269]

Abū Bakr ar-Rāzi describes the advanced beaked retort model in the part where he introduces the instruments used in chemistry:

"*The beaked retort and the distillation vessel are suitable for the distillation of waters. The secret is that the horned retort must be large and thick-walled, with no bubbles on its wall, preventing any splashes on its base and must sit perfectly upright. The cauldron in which the retort is placed must have the form of a pot and must be immersed in water to the highest level of the substance contained in the horned retort. The stove should also have a large cauldron with boiling water ready so that it can be refilled if the water in the (water bath) cauldron runs out. And avoid cold water coming into contact with the horned retort, and make it secure so that the horned retort does not move and does not touch the base of the cauldron, or it will break.*"[270]

Our model was built according to the description and drawings in the work.[271]

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267 This work has been translated into German by Julius Ruska. See: Julis Ruska, *Al-Razi's Buvh Geheimniss der Geheimnisse, Quellen und Studien zur Geschichte der Naturwissenschaften und der Medizin*, Band 6. Julius Ruska, Verlag von Julius Springer, Berlin 1937. Gail Taylor translated Ruska's German translation into English and published it along with a comprehensive analysis of the work: Gail Marlow Taylor, *The Alchemy of al-Razi: A Translation of the "Book of Secrets"*, Createspace Independent Publishing Platform, South Carolina 2014.

268 Taylor, *The Alchemy of al-Razi*, pp. 99-100.

269 Taylor, *The Alchemy of al-Razi,* pp. 35-89. See also: Gail Taylor, "The Kitab al-Asrar: An Alchemy Manual in Tenth-Century Persia", *Arab Studies Quarterly*, Vol. 32, No. 1 (2010), pp. 6-27.

270 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 4, p. 116.

271 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 4, p. 116.

DESCRIBED IN THE COSMOGRAPHY BOOK BY ŠAMS AL-DĪN AL-DIMAŠQĪ

66 A DISTILLATION APPARATUS

The cosmographer Šams al-Dīn Abū ʿAbd Allāh Muḥammad b. Ibrahīm b. Abī Ṭālib al-Anṣārī Šaykh al-Rabwa al-Dimašqī (d. 727/1327) authored awork titled *Nuḫbat al-dahr fī ʿağā'ib al-barr wa' l-baḥr*. In the section following the industrial rose water manufacturing processes he observed in the village of Mizza, he describes a distillation apparatus for distilling rose water, which he calls "al-zujāj al-ḥikmī".[1]

In this apparatus, which al-Dimašqī describes as one used by the Greeks and Arabs (referred to in the text as aḥl al-ḥikmah (people of wisdom)), the retort containing rose petals is not put directly over the fire, but on a second vessel containing water. This allows for tempering the heat such that the petals are not burned.

Nowadays, this "water-bath distillation method" is known as "Au Bain-Marie" (Latin: Balneum Mariae), which is French for "Mary's bath." This nomenclature is derived from an alchemist known in the West as Mary the Jewess and in Islamic sources as Māriya, who is believed to have lived in the first century.[2]

Mary's works are all known to be lost, however, when the references to Māriya's works made by another well-known alchemist in the Islamic tradition, Zosimos the Greek, are analysed, it becomes clear that Māriya made significant contributions to the discipline of chemistry.[3] Māriya invented a variety of methods for temperature-controlled distillation, in which the retort was positioned over manure, ash, or boiling water.[4] In this context, the reference of al-Dimašqī to Greek tradition in describing this apparatus demonstrates that he was aware of the apparatus' historical evolution. It is interesting to note thast the "Au bain marie" method, is still in use today, even in household kitchens.[5]

Our model was created in line with the illustrations in the work.[6]

1 Fuat Sezgin, *İslam'da Bilim ve Teknik*, vol. 4, p. 117. See also, ad-Dimašqī, Nuḫbat ad-Dehr fī 'Aǧā'ib wa-l-Baḥr, ed. A.F. Mehren, St. Petersburg 1866, p. 197-198; A. F. Mehren, *Manuel de la cosmographie du moyen âge*, Kopenhagen 1874, p. 266.

2 For example, in the tenth article of Ibn al-Nadīm's famous bibliographical work al-Fihrist, in which he introduces the ancient chemists/alchemists, her name is referred to as "Māriya" and two of her books titled *Kitāb al-Māriya al-Kibtiyye Ma'a al-Hukamā, Hīna İǧtama'ū Ilayhā and Kitāb Māriya al-Kabīr* are mentioned. See Muhammad b. Ishaq an-Nadīm, al-Fihrist, p. 887-889. For Mariya's life and works, see: Naomi Janowitz, Magic in the Roman World: Pagans, Jews and Christians (Religion in the First Christian Centuries), Routledge, New York & London 2001, p. 59-69.

3 Naomi Janowitz, *Magic in the Roman World: Pagans, Jews and Christians*, p. 65.

4 F.S. Taylor, "A Survey of Greek Alchemy", *The Journal of Hellenic Studies*, vol. 50 (1930), issue: 1, p. 116.

5 According to the current Turkish dictionary available on the website of the Turkish Language Association, the meaning of the word "benmari" is: a. "A method of heating or melting the contents of a container by placing it over boiling water."

6 Fuat Sezgin, *İslam'da Bilim ve Teknik*, vol. 4, p. 117.

ى عرضها القسي تحت مدلك الصورة

في السنا والرقو فينبغي ان ينظر فان كان الضرس قد بذب

ز ولم يتمكن بشره ولا برده فاقلعه وان كان ملصقا

ه بهذه الآله التي هذه صورتها وهي تسبه المثقار

دي حادة الطرف جدا ويكون قطعك له في ايام كثيره

لا من عرضها من الاضراس وان كان باتا متمكنا

برد من عند يكون هذه صورته

ند ونصابه منه دقيق النقش جدا يكون بها المبرد الذي

الضرس قليلا قليلا في ايام كثيره برفق لئلا من عرج الضرس

احرا وبرده بعض المبارد وان كان ضرس قد انكسر

دي اللسان عند الكلام فينبغي ان تبرده ايضا حتى يذهب

ي ويملاس ولا يؤذي اللسان ولا يفسد الكلام

Medicine

67
68

DESIGNED BY AL-ĞAZARĪ:

TWO INSTRUMENTS FOR MEASURING THE QUANTITY OF BLOOD AFTER BLOODLETTING

In Islamic medicine, which has built its foundations on the Greek medical tradition, diseases were based on a simple system, "Humoral Theory" or "Aḫlâṭ arbaʿa". According to this system, the health of the body depended on the balance of bodily secretions known as blood, phlegm, yellow bile and black bile. The balance would be disrupted as a result of an increase or decrease in one of these secretions and a disease would manifest. One of the methods used to restore the disturbed balance was to remove excess blood from the patient's body.[272]

For example, in the fourth chapter of his *Al-Qānūn fī ṭ-ṭibb* on treatment methods, the famous physician Ibn Sīnā writes about drawing blood from a vein (fī al-faṣd, Lat. Venesection, Greek. Phlebotomy), cupping(al-ḥiğāma) and leech therapy (fī al ʿilq) methods under three separate headings between chapters 20 and 22.[273]

Ḥiğāma, which was also known in the pre-Islamic period in the Middle East, was widely practiced in Islamic civilization. The main reason for this is that there are hadiths relaying that Prophet Muhammad applied and recommended this treatment.[274] Consequently, accepted as sunnah in Islamic civilization, this treatment was performed widely, discussed in general medicine books and even became an exclusive subject for books.[275] According to the veterinary texts written in the medieval Islamic civilization, the method of drawing blood from veins (faṣd) was applied not only to humans but also to animals.[276]

The Sultan he worked for asked Abu l-ʿIzz Ibn ar-Razzāz al-Ğazarī, who was working in the Artuqid Palace at the beginning of the 13th century, to write a work so that the tools he produced for him would not be lost, and to describe the construction of the tools he made in this work. Al-Ğazarī described the making of about 50 tools in his *al-Ğāmiʿ Bain al-*ʿİlm *wa-l-*ʿAmal *an-Nāfiʿ fī Ṣināʿat al-Ḥiyal*, which he wrote for this purpose.

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272 Peter E. Pormann & Emilie Savage-Smith, *Medieval Islamic Medicine*, Georgetown University Press, Washington 2007, p. 25.

273 İbn-i Sînâ, Esin Kahya (tr.), *al-Ḳânûn Fi'ṭ-Ṭıbb* : *Birinci Kitap*, Atatürk Kültür Merkezi Yayınları, Ankara 1995, pp. 320-337.

274 Abdullah Kose & Mahmut Rıdvanoğlu, "Hacamat", *DİA*, Vol. 14, p. 423. For a recent study and a list of literature in Turkish list, see: Büşra Yıldırım & Levent Öztürk, "Ebû Dâvûd's (d. 275/888) *Sünen* adlı eserine göre Hz. Peygamber döneminde Hacamat uygulamaları", *Uluslararası Sosyal Araştırmalar Dergisi*, p. 12 (2019), issue: 62.

275 Köşe & Rıdvanoğlu, "Hacamat", p. 422.

276 For information on this subject, see: Housni Alkhateeb Shahada, *Mamluks and Animals: Veterinary Medicine in Medieval Islam*, Brill, Leiden 2013, pp. 417-412.

The work describes four different instruments used to determine the quantity of blood after bloodletting under the headings of the fifth, sixth, seventh and eighth figures of the third type.[277] al-Ǧazarī's use of the word "faṣd" in the text shows that these instruments were designed to be used in drawing blood, rather than ḥiǧāma. At the beginning of the text, al-Ǧazarī writes, "Now, I will describe something I did. It is a vessel for blood drawn. It is based on a previous study. However, while it was only a globe lifted by blood, I produced it in various shapes." This statement reveals that this instrument was not his own invention and he improved on a simple tool he encountered in terms of function and aesthetics.[278]

All three of al-Ǧazarī's instruments were designed in such a way that the quantity of blood was measured by means of a float and the human figure pointed to the number representing the amount on the scale or plate. A priest standing on the first instrument shows the quantity of blood with his staff.

In contrast to al-Ǧazarī's first instrument called "The priest's vessel showing the amount of blood flowing into it", two and three human figures are used in the other three instruments. In the second model described in the section entitled "Vessel with two scribes where the amount of blood drawn is known", both the scribe in the circle and the scribe in the corner show the amount of blood drawn. The difference is that the scribe in the corner has a plate in his hand that rises as the amount of blood increases. Unlike the scribe in the circle, it is not the scribe's reed, but the plate, that is, the scale itself, that moves.

Our models are remakes of the first two examples.[279]

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277 Fazlıoğlu, Fazlıoğlu and Çalışkan, *Cezeri'nin Olağanüstü Makinaları*, Papersense Yayınları Istanbul 2015, Vol. II, pp. 73-104 (translation and technical description), p. 311 (summary description), Donald R. Hill, *The Book of Knowledge of Ingenious Mechanical Devices*, Pakistan Hijra Council, 1988, pp. 137-148 (translation), pp. 260-262 (technical description), pp. 210, 228, 229 (miscellaneous manuscript images).

278 Fazlıoğlu, Fazlıoğlu and Çalışkan, *Cezeri'nin Olağanüstü Makinaları*, p. 71 and p. 72 (technical description 5).

279 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 4, p. 35.

TECHNOLOGY IN THE MEDIEVAL ISLAMIC TRADITION OF MEDICINE

According to the Greek physician Galen (Ar. Ǧālinus), medicine is the art of recovering health when it is lost. According to Ibn Sīnā, medicine is the science that deals with the maintenance of good health and how one's health can be recovered in case of loss.[280] In the Islamic medical tradition, physicians applied many different treatment methods, from diet and exercise to medicine and surgery, for recovery.[281]

In Islamic medicine, which built its foundations on the Greek medical tradition, diseases were based on a simple system, "Humoral Theory" or " Aḫlâṭ arbaʿa ". According to this system, the health of the body depended on the balance of bodily secretions known as blood, phlegm, yellow bile and black bile. The balance would be disrupted as a result of an increase or decrease in one of these secretions and a disease would appear.[282]

The methods most preferred by the physicians were diet and exercise. Physicians worked on balancing factors outside of the patient's body, such as air, food and drink, sleep and waking, containment and excretion (from the gut, bladder, and reproductive organs), and mood/psychological state for the patient's recovery. For example, when the patient's mood needed to be improved, conversation or music therapy could be applied.[283] Apart from these methods, common treatment methods in the medieval Islamic medical tradition were bloodletting (faṣd, ḥiǧāma and leech) and cauterization.

Although Muslim physicians avoided surgical interventions, which were extremely dangerous due to the high probability of infection, they resorted to surgical methods when other treatment methods did not help.[284]

Surely, the first name that is associated with surgery is the Andalusian physician Abu l-Qāsim Ḫalaf b. ʿAbbās az-Zahrāwī (late 4th/10th century) and his encyclopedic work on medicine *Kitāb at-Taṣrīf li-man* ʿAǧiza ʿan *at-Taʾlīf* .[285] Although we know very little about his life, we may deduce from the name az-Zahrāwī that he was born in az-Zahrā, founded by ʿAbd al-Raḥmān al-Nāṣir, five miles west of Cordoba.[286]

280 Kahya*, al-Ḳânûn Fi Ṭıbb*, p. 1.

281 Peter E.Pormann, *The Mirror of Health: Discovering Medicine in the Golden Age of Islam*, Royal College of Physicians, London 2013, p.57.

282 Peter E. Pormann & Emilie Savage-Smith, *Medieval Islamic Medicine*, Georgetown University Press, Washington 2007, p. 25.

283 Peter E.Pormann, *The Mirror of Health: Discovering Medicine in the Golden Age of Islam*, Royal College of Physicians, London 2013, p.57.

284 Emilie Savage-Smith, "The Practice of Surgery in Islamic Lands: Myth and Reality", *Society for the Social History of Medicine,* 13 (2000), no: 2 (200), pp. 307-21.

285 Sami Khalaf Hamarneh, *A Pharmaceutical View of Abulcasis Al-Zahrāwī in Moorish Spain: with Special Reference to the "Adhān"*, EJ Brill, Leiden 1963.

286 M. S. Spink and G. L. Lewis, *On Surgery and Instruments*, The Wellcome Institute of the History of Science, p. vii.

At-Taṣrīf, whose reputation spread rapidly in the Islamic world, was translated into Latin under the title *Liber Alsaharavi de Cirurgia* by Gerard of Cremona in Toledo in the second half of the 12th century, and thanks to this translation, it influenced French and Italian physicians.[287]

Some parts *of Kitāb at-Taṣrīf* by az-Zahrāwī, who became famous with the name Albucasis, were translated into Latin and other languages. The last part of the book, which deals with the subject of surgery, particularly attracted great attention and was published separately. This work is the first illustrated surgery book in history.

Although az-Zahrāwī largely made use of the works by Byzantine physician Paul of Aegina (625-690 AD) and his other forerunners in the part of the work on surgery, the fact that he shared his personal experiences in many instances shows that he was really a physician. Furthermore, az-Zahrāwī also mentions many surgical methods and instruments that are not mentioned in ancient medical works.[288]

287 Spink and Lewis, *On Surgery*, p. vii.

288 Spink and Lewis, *On Surgery,* p. ix.

FOR THE REMOVAL OF TARTAR

69 14 RASPATORIES (SCRAPER)

Az-Zahrāwī (4th/10th century) describes dental instruments in the 30th treatise of his *Kitāb at-Taṣrīf* and introduces 14 raspatories for the removal of tartar. Realizing that tartar caused deterioration of the gums and created a negative effect, az-Zahrāwī wrote:

"Sometimes, on the surface of the teeth, inside and outside the teeth and between the gums, unsightly hard tartar in (colors of) black, green or yellow forms from which deterioration spreads to the gums and the teeth become ugly. Place the head of the patient sitting in front of you on your lap, between your legs, and scrape the teeth and molars on which you see something like crust or sand, until nothing is left, and do so with everything black, green, yellow (colored) and so on, until they are all gone.

If the first scraping is not sufficient, scraping should be continued the next day and, if necessary, a third or even fourth scraping should be done until the teeth are free of tartar. You should know that you will need scraping instruments in different forms and shapes depending on the type of teeth and the work you are going to do, because the tool used to scrape the inner surface is different from the one used to scrape the outer surface of the teeth, and a completely different instrument will be required to scrape between the teeth. You should have these raspatories ready with you."[289]

Our models are built after the drawings in the Paris, Oxford and Beşirağa (Istanbul) manuscripts of *Kitāb at-Taṣrīf*.[290]

289 (Translated into Turkish by me) Spink & Lewis, *On Surgery*, pp. 272-275.

290 Sezgin, İslam'da *Bilim ve Teknik*, Vol. 4, p. 61., Inv. No. H 9.01

70 STAMP SYRINGE

Described by az-Zahrāwī (4th/10th century), this tool was used to treat boils, blood clots or pus in the bladder. This instrument, which was made of ivory or silver, was used to inject drugs in liquid form into the bladder through the urethra. This tool was used for the first time in Islamic civilization as only balloon syringes were known in antiquity.[291]

Our model was built based on the drawings in the work.[292]

291 Spink and Lewis, *On Surgery,* p. ix and pp. 406-409.

292 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 4, p. 70., Inv. No. H. 5.06

TWO-LEAVES VAGINAL SPECULUM

71

Known to have been used since the 2nd century BC, this device is designed for cervical and intrauterine interventions.[293] We know this from the notes of Archigenes describing how it was used in the surgeries of the cervix and abscesses. In his book on medicine, Soranus of Ephesus allocated a section to the vaginal speculum.[294] Az-Zahrāwī did not specifically name these speculums and only explained them in descriptive terms in his *at-Taṣrīf*.[295]

Our model was built based on the drawings in the work.[296]

293 Spink and Lewis, *On Surgery*, p. 484.

294 Spink and Lewis, *On Surgery*, p. 484.

295 Spink and Lewis, *On Surgery*, p. 484.

296 Sezgin , İslam'da *Bilim ve Teknik*, p. 74. Inv. No. H 6.04

72 CEPHALOTRIBE I (MİŠDĀḪ)

Az-Zahrāwī described this instrument as a cutting and crushing instrument used to remove the dead fetus from the mother's womb in case of miscarriages.[297] This instrument can be considered the predecessor of the 'obstretic forceps' used today in difficult deliveries. The key difference between the instrument described by az-Zahrāwī and the modern obstretic forceps is that the modern forceps is wider and is not toothed.

Our model is based on the drawings in the work.[298]

297 Spink and Lewis, *On Surgery*, p. 484, .p.490

298 Sezgin*, İslam'da Bilim ve Teknik*, p. 78, Inv. No H. 6.02

CEPHALOTRIBE II (MİŠDĀḪ)

73

A second type of Cephalotribe described by az-Zahrāwi in *at-Taṣrīf*, is also for intrauterine cutting and crushing, and can be said to be the predecessor of the "tenaculum/single toothed clamp", which continues to be used for the same purpose today.

Our model is based on the drawings in the work.[299]

CEPHALOTRIBE III (MİŠDĀḪ)

74

A third type of Cephalotribe described by az-Zahrāwi in *at-Taṣrīf*, is a type of pliers with no curved tip as opposed to the first instrument that he describes as "scissor-like".[300] A similar instrument, which is also used for crushing and cutting purposes, is widely used today under the name of "toothed clamp/kocher".

Our model was built according to the drawings in the work.[301]

299 Sezgin, *İslam'da Bilim ve Teknik*, p. 79, Inv. No. H. 6.03

300 Spink and Lewis, *On Surgery*, p. 492.

301 Sezgin , İslam'da *Bilim ve Teknik*, p. 79, Inv. No. H. 6.06

75 SCISSOR-LIKE INSTRUMENT

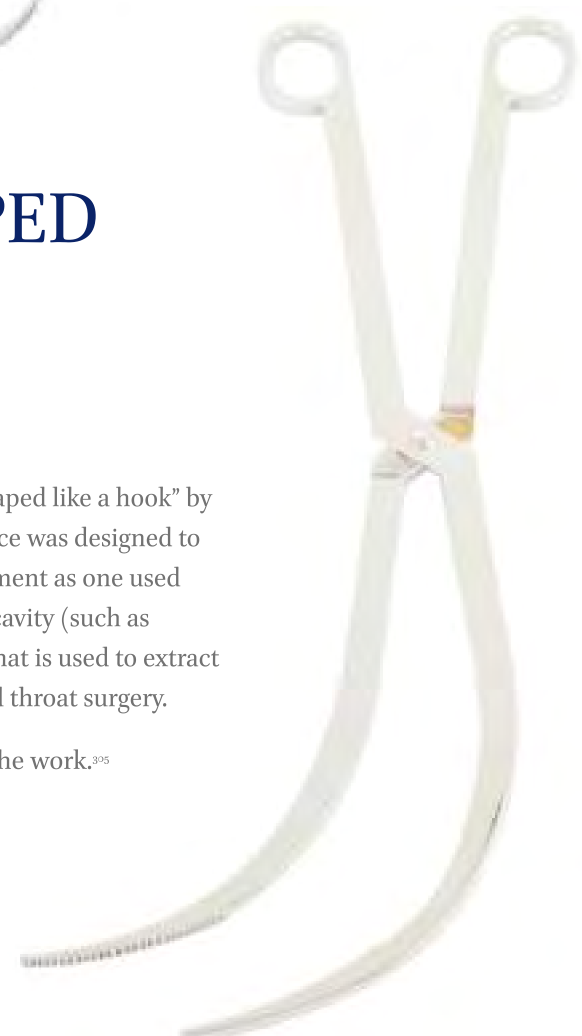
(ĀLA TUŠBIHU L-MIQAṢṢ)

The instrument described as "scissor-like" by az-Zahrāwi is used for removing swollen tonsils and catching and extracting tumors of the pharynx.[302] This instrument called "babcock" is widely used in various surgical operations and procedures with the same form today.

Our model has been built according to the drawings in the work.[303]

76 INSTRUMENT SHAPED LIKE A HOOK

(ĀLA TUŠBIHU L-KALĀLĪB)



The edges of the instrument described as "instrument shaped like a hook" by az-Zahrāwi are tilted as a bird's beak and the jagged surface was designed to hold objects firmly. Az-Zahrāwi has described this instrument as one used for the extraction of foreign bodies from the pharyngeal cavity (such as leeches).[304] This instrument is similar to "magill forceps" that is used to extract foreign bodies from the pharyngeal cavity in ear-nose and throat surgery.

Our model has been built according to the drawings in the work.[305]

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302 Spink and Lewis, *On Surgery*, p. 300.

303 Sezgin, *İslam'da Bilim ve Teknik*, Vol.4, p. 57, Inv. No. H 4.05

304 Spink and Lewis, *On Surgery*, p. 318, fig. 83.

305 Sezgin, *İslam'da Bilim ve Teknik*, p. 58, Inv. No. H. 4.13

SCALPEL I (MİBḌAʿ RAQĪQ)

77

Az-Zahrāwi describes this instrument in *at-Taṣrīf* as an instrument that serves to disintegrate grains or seeds that have gotten into the ear and have swollen up due to the moist inside the ear.[306] Today, this scalpel is widely used with the same form in all kinds of surgical procedures as the number 11 scalpel blade .

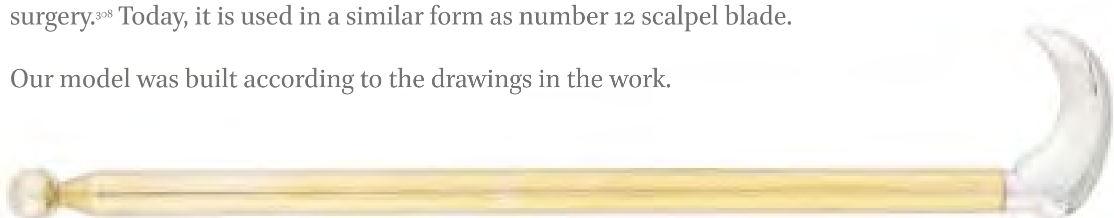
Our model was built according to the drawings in the work.[307]

SCALPEL II (MİBḌAʿ)

78

In *at-Taṣrīf* az-Zahrāwi describes this type of scalpel as an instrument that can be used in tonsil surgery.[308] Today, it is used in a similar form as number 12 scalpel blade.

Our model was built according to the drawings in the work.



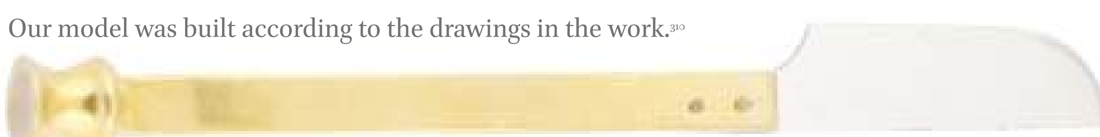
(MIBḌAʿ LI-QAṬʿ AẒ-ẒAFRA WA-NUTŪW LAḤM AL-ĀMĀQ)

SCALPEL III

79

In *at-Taṣrīf* az-Zahrāwi describes this type of scalpel as an instrument used in soft tissue surgical procedures around the eyes.[309] Today, this type of scalpel is widely used in all kinds of surgical procedures as the number 20 scalpel blade in the same form.

Our model was built according to the drawings in the work.[310]



306 Spink and Lewis, *On Surgery*, p. 194, fig. 47.

307 Sezgin, *İslam'da Bilim ve Teknik*, p. 55, Inv. No. H 4.09

308 Spink and Lewis, *On Surgery*, p. 302, fig. 79.

309 Spink and Lewis, *On Surgery*, p. 330, fig. 55.

310 Sezgin, *İslam'da Bilim ve Teknik*, p. 47, Inv. No. H 2.06

80 HOOKS/RAKE RETRACTOR (ṢİNNĀRA)

In *at-Taṣrīf,* az-Zahrāwi describes several different types of hooks. The purpose of this tool is to hold back the muscles and skin.[311] Az-Zahrāwi, describes 3 different models; one with a single prong, one with two prongs and one with three prongs, and he explains that the instruments are used to pull back the skin to the sides while opening swollen inflammations, catching warts, and performing tracheotomy procedures, as well as the removal of dead fetuses and hemorrhoid treatment. Today, these tools are widely used in similar forms for stretching and holding back tissue.

Our models were built according to the drawings in the work.[312]

311 Spink and Lewis, *On Surgery*, p. 352, fig. 102-106.

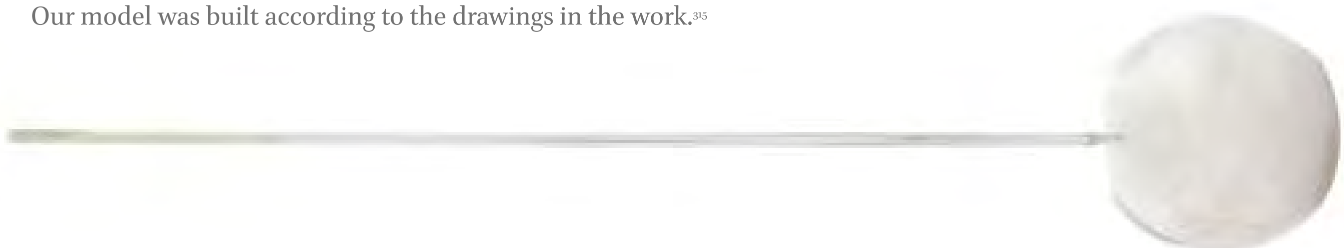
312 Sezgin, *İslam'da Bilim ve Teknik*, Vol.4, p. 69, Inv. No. 5.01

CATHETERS/BLADDER CATHETERS (QĀṮĀTĪR)

81

Bladder catheters have a very old history.[313] According to Galen, Erasistratus was the first to use the name catheter. Az-Zahrāwi used the word in its original Greek form and described its form and methods of use in detail.[314] Today, bladder catheters are widely used for the same purpose.

Our model was built according to the drawings in the work.[315]



CATARACT NEEDLE (MIQDAH)

82

Although cataract disease was known by the Greek physician Celsus, cataract surgery was described with three different instruments in az-Zahrāwi's *at-Taṣrīf.* He describes in detail the treatment method by which the patient's vision could be restored with an intervention to the opacified eye lens.[316] Today, the type of blade used in this surgical procedure performed with advanced robotic devices is similar in shape to the needle described by az-Zahrāwi.

Our model was built according to the drawings in the work.[317]

313 Spink and Lewis, *On Surgery*, p. 402, fig. 133.

314 Spink and Lewis, *On Surgery*, s. 402.

315 Sezgin, İslam'da *Bilim ve Teknik*, p. 69, Inv. No. H 5.01

316 Spink and Lewis, *On Surgery*, p. 252, fig. 62.

317 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 4, p. 44, Inv. No. H 2.13

83 CAUTER

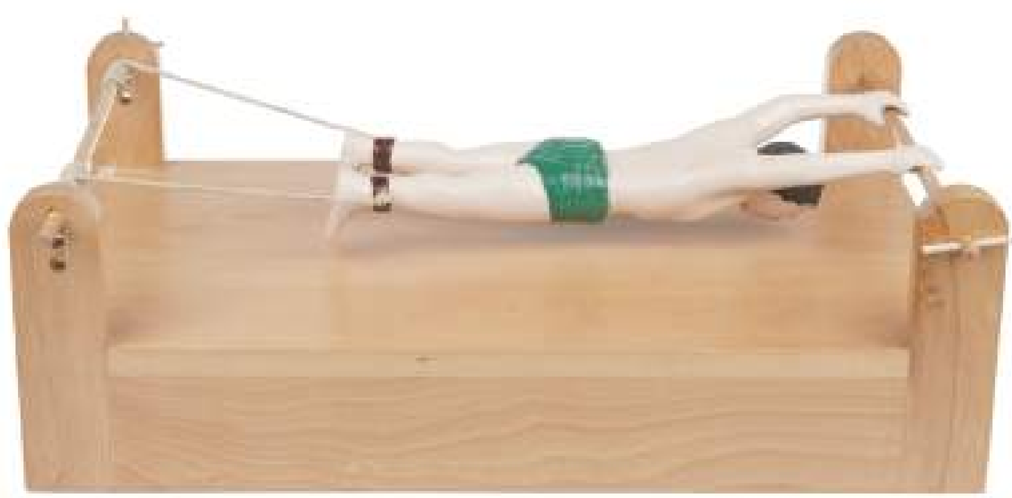
In *at-Taṣrīf*, az-Zahrāwi allocated ample space for cauterization, which was widely used in ancient and medieval medicine. One of these cauters is the model used to treat cleft lip (hare lip) (mikwāt ṣaġīra sikkīnīya li-kaiy ṣiqāq aš-šafa).[318] Today, cauterization is widely used in all types of surgery to control bleeding and cut tissue. In the past, cauters were heated on fire while today electricity is used as a power source.

Our model was built according to the drawings in the work.[319]

84 ORTHOPAEDIC BENCH

This instrument, described by az-Zahrāwi (4th/10th century) in *the* 30th treatise of his book *Kitāb at-Taṣrīf*, was used for the treatment of dislocations of the dorsal vertebrae.[320]

Our model was built according to the drawings in the work.



318 Spink and Lewis, *On Surgery*, p. 60, fig. 14.

319 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 4, p. 41, Inv. No. H 1.10

320 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 4, p. 82. Inv. No.H 3.05

خامسة

فكثيرا أما تعود فاقطعه ثانية واكوه فإنه لا يعود بعد الكي

١٣٩ في جرد الأسنان بالحديد

قد يجتمع في سطوح الأسنان من داخل ومن خارج وبين اللثات قشور خشنة قبيحة وقد تسود وتصفر وتخضر حتى يحصل من ذلك فساد إلى اللثة وتقبح الأسنان لذلك فينبغي أن يجلس العليل بين يديك ورأسه في حجرك وتجرد الضرس والسن الذي ظهر لك فيه القشور والشيء الشبيه بالرمل حتى لا يبقى منه شيء وكذلك تفعل بالسواد والخضرة والصفرة وغير ذلك حتى تنقى فإن ذهب ما فيها من أول الجرد وإلا فتعيد عليه الجرد يوما آخر وثانيا وثالثا حتى تبلغ الغاية فيما تريد واعلم أن الضرس يحتاج إلى مجارد مختلفة الصور كثيرة الأشكال على حسب ما يتهيأ لعملك من أجل أن المجرد الذي يجرد به الضرس من داخل غير المجرد الذي يجرد به من خارج والذي يجرد به الضرس من داخل غير المجرد الذي يجرد به من خارج والذي يجرد به من الأضراس على صورة أخرى ۝ وهذه عدة صور مجارد تكون عندك كلها معدة

85 SULTAN BAYEZID II HOSPITAL

This hospital, a part of the complex built by the Ottoman Sultan Bayezid II on the banks of the Tundzha River in Edirne between 1484-1486, is one of the most important structures that have survived from Ottoman medical history. All parts of this complex, located in Yeniimaret district of the city of Edirne , today, have been turned into a museum within the organization of Trakya University, except for the mosque.[15]

The most important historical sources about the operation of the hospital are three endowments of the complex (one in Arabic and two in Turkish dated 1487, 1490 and 1493) that have survived to the present day.[16]

The most interesting aspect of the hospital, apart from the normal treatment procedures, was the therapy for psychological patients with music and the sound of water.
According to Evliyā Çelebī (11th/17th century Ottoman traveller), a team of 10 people would come to the hospital three times a week and perform music concerts in different modes according to the needs of different patients.[17] In addition, three of these ten-member team were reciters, not musicians, and they would recite poems and stories to patients.[18]

Evliyā Çelebī describes his experiences in his *Seyahatname* as:

«I have seen a remarkable thing: His late majesty, Bajezid…has employed 10 musicians for the cure of patients in the endowment document, for the recovery of those suffering from pain, for strenthening the mind of the insane and for repelling the gall: 3 of them are singers; of the remaining, one players each of the reed flute (nāyzen), the fiddle (kemānī), the panpipes (mūsīqārī), the dulcimer (ṣantūrī), the harp (ǧengī), the harp psalterion (? ǧengī-ṣantūrī) and of the lute ('ūdī). They come three times a week and play for the patients and the insane. By the grace of the Almighty many of them feel relief. In fact, according to the science of music, makams nevā, rāst, dügāh, segāh, čārgāh and sūzināk are intended for these [patients and insane]. But when the makams zengüle and būselik [are played] and concluded with the makam rāst, then it is as if they are brought new life. In all instruments and modes there is food for the soul.»[19]

Evliyā Çelebī narrates that in addition to music therapy, aromatherapy would also be applied to patients in the hospital.[20]

[15] Hilal Yılmaz, "Edirne II. Sultan Beyazid Darüşşifasındaki Görevliler ve Görevleri", içinde: A. R. Aydın, İshak Keskin, N. Z. Yelçe (ed.), *Engellilik Tarihi Yazıları*, İstanbul Üniversitesi Yayınları, İstanbul, 2020, p-119-132. p. 119
[16] Hilal Yılmaz, "Edirne II. Sultan Beyazid Darüşşifasındaki Görevliler ve Görevleri", p.123-124
[17] Hilal Yılmaz, "Edirne II. Sultan Beyazid Darüşşifasındaki Görevliler ve Görevleri", p.129
[18] Miri Shefer-Mossensohn, *Ottoman Medicine: Healing and Medical Institutions, 1500-1700*, State University of New Press, New York, 2009, p. 74
[19] Fuat Sezgin, *İslam'da Bilim ve Teknik*, vol. 5, p.75
[20] Hilal Yılmaz, "Edirne II. Sultan Beyazid Darüşşifasındaki Görevliler ve Görevleri", p.130

86 NŪRADDĪN HOSPITAL

One of the most important hospitals in the history of Islam, this hospital was founded by the Turkish ruler and commander Nūraddīn Maḥmūd b. Zanǧī soon after the city of Damascus was liberated from Mongol invasion (549/1154).[321] One of the major historical buildings in the city of Damascus, the hospital continued to serve in the 19th century. The hospital consisted of a central courtyard and four īwāns around this courtyard. There was a fountain in the center of the courtyard, and in front of one of the īwāns, there was a rectangular structure with a muqarnas portal and a dome.

The most interesting source about the early functioning of the hospital is the famous Andalusian traveler Ibn Ǧubair. Ibn Ǧubair says the following about this hospital in his travelogue:

"Here (Damascus) there are about twenty schools and two hospitals, one new and one old. The new one has more visitors and is larger. Its daily cost is about fifteen dinars. There, there are employees who are responsible for recording the names of the patients, the necessary expenses for medicines and patient care, etc. Physicians come every day early in the morning, examine the patients and, taking into account the condition of each patient, arrange the necessary medicines, care and food... They also treat mental patients there."[322]

Hospital doors are a strong proof of how mathematics, crafts and art come together in Islamic architecture. Geometric patterns were created with brass nails on the wooden doors covered with bronze sheets.[323] Interestingly, we have detailed information about the name and life of the master who made the doors of this hospital thanks to the famous ophthalmologist and biographer Ibn Abī Uṣaibiʿa (d. 668/1269).

The historian of Islamic art Yasser Tabbaa writes the following about the master who built this door:

"The logic, originality and beauty of this geometric design testify to the genius of its maker, al-Muhandis. According to Ibn Abī Uṣaibiʿa, he made this door and most of the others that once existed in the Bimaristan. He was known as a carpenter, stonemason, and geometer or engineer who had studied *Euclid* and the *Almagest* in order to excel in his crafts. Interestingly, he also read astronomy and medicine as well as hadith, grammar, and poetry and even wrote treatises in science and literature. In other words, he was an artisan, a scientist, and a man of letters, a combination that, although questioned by many writers on Islamic art, may have been fairly commonplace in medieval Islam."[324]

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321 See: Bahattin Kök, "Nūreddīn Zengī", *DİA*, Türkiye Diyanet Vakfı Yayınları, Istanbul, 2010, Vol. 33, pp. 259-262.

322 Sezgin, *İslam'da Bilim ve Teknik*, v. 5, p. 68.

323 Yasser Tabbaa, *The Transformation of Islamic Art During the Sunni Revival*, University of Washington Press 2001, p. 88.

324 Tabbaa, *The Transformation,* p. 88.

87 THE QALĀWŪN HOSPITAL

Another famous hospital in Islamic history is the hospital founded by the Mameluk Sultan al-Melik al-Manṣūr Saifaddīn Qalāwūn (678-689/1279-1290). According to the historian al-Maqrīzī (766/1364-845/1422), while Sultan Qalāwūn was still a commander, he fell ill with severe colic in Damascus during an expedition in 1276, and physicians treated him with medicines brought from Nūraddīn Hospital.[325] After his recovery, Qalāwūn visited the hospital which he liked very much and vowed that he would build a hospital if God gave him the throne. Then, when he became sultan, he set out to fulfil his vow and commissioned the building of the hospital known as the Qalāwūn Hospital. The Sultan not only built the hospital, but also endowed property to cover the hospital's expenses.

According to al-Maqrīzī, when the hospital was completed, Sultan Qalāwūn, "endowed for it so much land in Egypt and other countries that every year an income of nearly one million dirhams was received, and he determined the places where the money for the hospital, the house of prayer, the academy and the school for orphans should be allocated." Al-Maqrīzī also quotes the sultan's speech on the occasion of the establishment and opening of the hospital as follows:
"Then he drank a glass full of drink and said: 'This I have endowed for my equals and for those lesser than I am, I have designated it as an endowment for the king and for the servant, for the soldier and for the commander, for the big and for the small, for the free man and for the slave, for men and women'".[326] Al-Maqrīzī also relates that the sultan determined for the hospital "the medicines, the physicians and everything else that may be needed there during any illness", and appointed male and female bed-makers to serve the patients, allocating salaries to them, and had beds established for the sick.[327]

Different rooms of the hospital were allocated to different patient groups.[328] For example, four big wards of the hospital were allocated for those suffering from fever and similar illnesses. One ward was designated for those suffering from eye diseases, and each of the other ones were allocated for the wounded, for those who suffered from diarrhea and for women. The hospital also housed a kitchen, a pharmacy, and a school where medical lectures were delivered.[329]

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325 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 5, p. 71, footnote 1.

326 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 5, p. 72, footnote 1 (continued).

327 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 5, p. 72, footnote 1 (continued).

328 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 5, p. 72, footnote 1 (continued).

329 Sezgin, *İslam'da Bilim ve Teknik*, Vol. 5, p. 73, footnote 1 (continued).

Although this hospital has not survived to the present day, there are sources and documents related to the hospital. In addition to the information given by historians about the purchase of the hospital land, the construction and opening of the hospital, there are also two endowment documents and a chief physician appointment document that have survived to the present day.[330] This appointment document stresses that the duty of the chief physician is not only to manage hospitals and doctors, but also to develop himself in his profession.[331]

Famous for his discovery of microcirculation, ʿAlī b. Abi l-Ḥazm Ibn an-Nafīs (d. 687/1288) probably worked in this hospital and endowed his library to this hospital.[332]

330 Linda S. Northrup, Qalawūn´s Patronage of the Medical Sciences in Thirteenth-Century Europe, *Mamlūk Studies Review*, Vol.5 (2001), pp.119-140.

331 Northrup, Qalawūn´s Patronage, pp. 123-124.

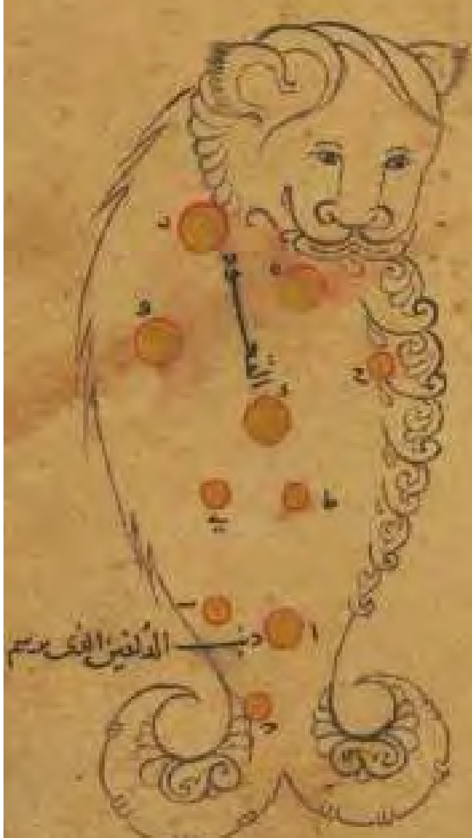
332 Northrup, Qalawūn´s Patronage, pp. 123.

کواکب دلفین

و دلفین از حیوانات بحریست و کواکب این صورت ده است مجتمع در میان نسر طایر و کوکب اول کوکبی
روشن است که بر دنبال است از اعظم قدر چهارم و بطلمیوس از اصغر سیوم آورده و این کوکب را بر سطرلاب
معین کنند و ذنب الدلفین خوانند و دوم کوکبی شمالی است از آن دو کوکب که تالی او اند و از قدر سیوم
است و سیم کوکبی جنوبی است از همان دو کوکب و از قدر ششم است و چهارم جنوبی است از آن دو کوکب متقدم
از جمله مربعی که شبیه است بمعین و پنجم شمالی همان دو کوکب است و ششم جنوبی است از آن دو کوکب تالی از معین
و هفتم شمالی همان دو کوکب است و این چهار از اصغر قدر سیم اند و هشتم در میان چهار است
از قدر ششم و میان [illegible] باشد و نهم کوکبی متقدم است از آن دو کوکب تاریک
که میان ذنب الدلفین اند و میان [illegible] که از معین باو و دهم تالی همان دو کوکب است و هر دو از قدر
ششم اند و عرب این چهار کوکب را که بر شکل معین اند و آن چهارم و پنجم و ششم و هفتم است عقد خوانند
و عوام عرب چهار را صلیب خوانند و ذنب الدلفین را عمود الصلیب و صورت دلفین اینست

صورت دلفین چنانک بر کره بینند

صورت دلفین چنانک بر آسمان بینند



...مان بینند

Manuscripts

88 RİSĀLA FĪ KAIFĪYAT AL-ARṢĀD WA-MĀ YUḤTĀǦU İLĀ ʿİLMİHĪ

MUʾAİYADADDĪN AL-ʿURḌĪ (10TH CENTURY)

National Palaces, Topkapı Palace Library, Ahnet III 3329

Written by Muʾaiyadaddīn al-ʿUrḍī, who served at the Maragha Observatory, this work offers descriptions and drawings of the observation instruments produced for the observatory. The observation instruments of the Maragha Observatory in our collection were constructed on the basis of this manuscript.

TRANSLATION OF KITĀB ṢUWAR AL-KAWĀKIB

89

ʿABDARRAḤMĀN AṢ-ṢŪFĪ (AUTHOR) / NAṢĪRADDĪN AṬ-ṬŪSĪ (TRANSLATOR)

TYEK, Süleymaniye Library, Ayasofya 2595

The famous astronomer ʿAbdarraḥmān aṣ-Ṣūfī´, who lived in the 10th century, wrote a catalogue of stars entitled *Kitāb Ṣuwar al-Kawākib*. This work, which also includes depictions of constellations, was very influential not only in the Islamic world but also in Europe. The manuscript on display contains the Persian translation of *Kitāb Ṣuwar al-Kawākib* by Naṣīraddīn aṭ-Ṭūsī (13th century), the founder of the Maragha Observatory. The manuscript is an extremely valuable copy because it was copied for Uluġ Beg's library in Samarkand.

90 KITĀB FĪ MĀ YAḤTĀJ ILAYH AL- ṢĀNIʿ MIN AL-AʿMĀL AL-HANDASIYYA

ABU L-WAFĀʾ AL-BŪZAĞĀNĪ (10TH CENTURY)

TYEK, Süleymaniye Library, Ayasofya 2753

In *Kitāb fī mā yaḥtāj ilayh al- ṣāniʿ min al-aʿmāl al-handasiyya,* which he wrote for craftsmen as he was not content with their "approximate" geometrical methods, the 10th century mathematician and astronomer Abu l-Wafāʾ al-Būzağānī describes how to draw geometric shapes such as different polygons with compass and ruler. Although he gives step by step instructions for drawing geometric shapes with the "compass-ruler construction" method, the author does not give mathematical proofs in this work, which is more of a practical manual as it was written for craftsmen.

This copy, which is the most beautiful known copy of the work with its script and geometric drawings in gold ink, is a very valuable manuscript because it was copied for the library of Uluğ Beg, the founder of the Samarkand Observatory.


كتاب ابي الوفا فيما يحتاج اليه
من اعمال الهندسة
٢٧٥٤
Mikrofilm Arşivi
No. 375

91 ĀLĀT AR-RAṢADĪYA LĪ ZĪĞ-İ ŠAHİNŠAHĪYA

SEYYID LOKMAN (16TH CENTURY)

National Palaces, Topkapı Palace Library, Ahnet III 3329

Written while the Istanbul Observatory was active (1574-1580 AD), this work includes brief descriptions and miniature versions of the observation instruments used in the observatory. Observatory instruments of the Istanbul Observatory in our collection were produced on the basis of manuscript.

92 SİDRAT MUNTAHĀ AL-AFKĀR FĪ MALAKŪT AL-FALAK AL-DAWWĀR

TAQĪYADDĪN MUḤAMMAD B. MAʿRŪF (16TH CENTURY)

Boğaziçi University, Kandilli Observatory, No. 208/1

This manuscript, which is the draft autograph manuscript of *Sidrat Müntahā* written by Taqiyaddīn based on his observations in the Istanbul Observatory is one of the most significant manuscripts that have survived to the present day in the history of Islamic science for two reasons. First of all, although there are many astronomical handbooks, which are called zīj in the history of astronomy, those that explain how new data emerging from an extensive observation program were used, which observation data were used, and how the calculations were made, are very rare .

The second reason is that since this manuscript is a draft autograph manuscript, it contains sentences that were canceled, added and changed, and only calculations with results are included in the main text. Such draft manuscripts are almost non-existent. This manuscript makes it possible for us to see how an Islamic astronomer proceeded step by step, based on his observations in the observatory, and the kind of working method he followed.

93 AL-MUQADDİMAH

IBN ḪALDŪN (14TH-15TH CENTURY)
TYEK, Süleymaniye Library, Atif Efendi 1936

The first part, which was written by Ibn Ḫaldūn as an introduction to *Kitāb al-ʿibar fī aḫbar al-ʿ*Arab *wa- al-ʿAjam wa-al-Barbar*, attracted a great deal of attention due to its interesting sociological analysis and conclusions, and started to be reproduced as an independent work under the name *Al-Muqaddimah.* Dated 804/1401-2, this manuscript, is very important for two reasons. First of all, of the many copies of Ibn Ḫaldūn's work that have survived, only a few have al-Idrīsī's world map. Ibn Ḫaldūn, who was influenced by and benefited from the geographical works of al-Idrīsī, gives information about this map in the copies that has the map. Another significance of this manuscript is that there is a note handwritten by Ibn Ḫaldūn on the first page.

94 AL-ĞĀMIʿ BAIN AL- ʿILM WA-L-ʿAMAL AN-NĀFIʿ FĪ ṢINĀʿAT AL-ḤIYAL

BADĪʿAZZAMĀN ABU-ʾIZZ ISMĀʿĪL IBN AR-RAZZĀZ AL- ĞAZARĪ (12TH-13TH CENTURY)

National Palaces, Topkapı Palace Library, Ahnet III 3472

Al-Ğazarī wrote *Al-* Ğāmiʿ *bain al-* ʿilm *wa-l-* ʿamal-an-nāfiʿ *fī ṣināʿat al-ḥiyal* at the request of the Artuqid ruler Emir Nāṣīraddīn Maḥmūd, whom he served, describing the instruments he invented. The work includes skillful drawings accompanying the text which describes 50 different inventions such as clocks, pumps, fountains, and lock mechanisms. The most valuable manuscript of this work, which has survived to our day in multiple manuscripts, is the present manuscript, which is also the oldest manuscript and was copied from an original manuscript by al-Ğazarī in 1206.

KİTĀB AL-MANĀẒİR

ABŪ ʿALĪ MUḤAMMAD B. AL-ḤASAN B. AL-ḤASAN IBN AL-HAIṮAM (10TH-11TH CENTURY)

TYEK, Süleymaniye Library, Fatih 3212

95

Among the surviving manuscripts of *Kitāb al-Manāẓir*, the most comprehensive and important work written by the Islamic scholar Ibn al-Haiṯam, known for his works on optics, is the set known as the “Askari Set” in the Süleymaniye Library. This set, of which we are exhibiting only one volume, is one of the most valuable manuscripts in the history of Islamic science, since it is very old and was produced by the author’s son-in-law.

96 CONICS/ʿİLM AŠKĀL QUṬŪ AL-MAḪRŪṬĀT

APOLLONIUS OF PERGA (3RD CENTURY BC) / IBN AL-HAIṮAM (10TH-11TH CENTURY)

TYEK, Süleymaniye Library, Ayasofya 2762

The work by Apollonius, who lived in the 3rd century BC, on conic sections is one of the most important mathematical works written in antiquity. The first 4 chapters of the work, which consists of 8 chapters, have survived in Greek to the present day, and 7 chapters have survived from the Arabic translation made in Baghdad in the 9th century. This manuscript is extremely valuable because it was written by Ibn al-Haiṯam himself. Historical sources report that Ibn al-Haiṯam earned his living by copying manuscripts. This manuscript is likely to be one of those.

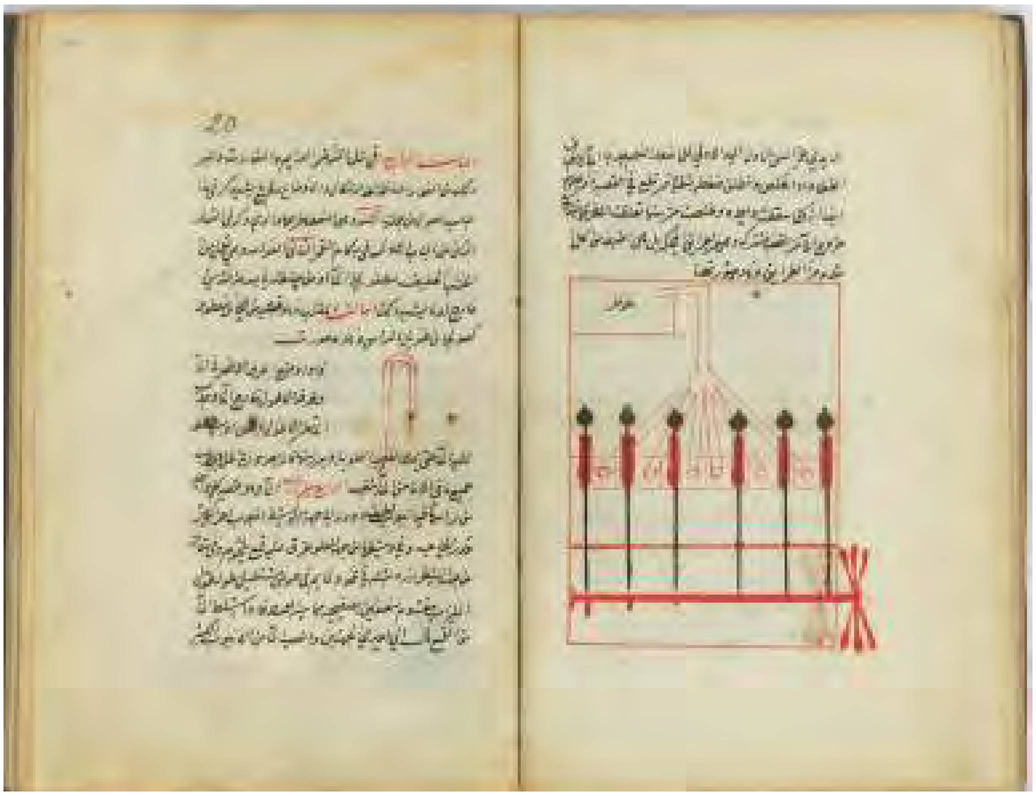
KITĀB AL-ḤIYAL

BANŪ MŪSĀ B. ŠĀKIR (9TH CENTURY)

National Palaces, Topkapı Palace Library, Ahnet III 3374

97

Three of the 4 extant manuscripts of *Kitāb al-Ḥiyal´* are incomplete. The Banū Mūsa brothers, who lived in Baghdad in the 9th century and produced works in many fields, describe approximately a hundred instruments in this work. Among these manuscripts, the most valuable one is this manuscript in Topkapı Palace, due to the fact that there are only a few errors in its text and drawings.



98

AṬ-ṬURUQ-AS-SANĪYA FI L-ĀLĀT AR-RŪḤĀNĪYA

TAQĪYADDĪN MUḤAMMAD B. MAʿRŪF AR-RAṢṢĀD (16TH CENTURY)

Boğaziçi University Kandilli Observatory Library, No. 96

Taqīyaddīn, who is best known as an astronomer, tells about the different instruments he invented in his work titled *Aṭ-Ṭuruq as-Sanīya fi- l-Ālāt ar-Rūḥānīya,* which he wrote in his youth. The most interesting of these inventions is the 6-piston water pump, which was a pioneer for its time. This manuscript, which is in the Kandilli Observatory Library, is among the most important manuscripts in the history of Islamic science, as it is an autograph copy.

KİTĀB KĪMİYĀ’ AL-‘IṬR WA-T-TAṢ‘ĪDĀT

99

ABŪ YŪSUF YA‘QŪB B. ISḤĀQ AL-KINDĪ (9TH CENTURY)

TYEK, Süleymaniye Library, Ayasofya 2594

Known to have written hundreds of works, al-Kindī also wrote valuable works on chemistry. In this work he wrote on perfume chemistry, he gives 107 different perfume and cosmetic recipes. One of the interesting points in the work is that perfumes are handled not only in terms of scent but also in terms of aesthetics. In some recipes, al-Kindī describes which herbs can be used to give a beautiful color to the perfume produced. Another interesting aspect of the work is that al-Kindī gives recipes where similar scents can be obtained with cheaper materials as an alternative to scents with expensive ingredients. This manuscript, is very valuable as it is a very old manuscript.

100 KITĀB AT-TAṢRĪF LI-MAN ʿAĞIZA ʿAN AT-TAʾLĪF

ABU L-QĀSIM ḪALAF B. ʿABBĀS AZ-ZAHRĀWĪ (LATE 4TH/10TH CENTURY)

TYEK, Beyazıt Manuscript Library, Veliyüddin 2491

Surely, the first name that is associated with surgery is the Andalusian physician Abu l-Qāsim Ḫalaf b. ʿAbbās az-Zahrāwī (late 4th/10th century) and his encyclopedic work on medicine *Kitāb at-Taṣrīf li-man* ʿAğiza ʿan *at-Taʾlīf.* The last part of this work, which consists of 30 chapters, is about surgical instruments. This section received special attention at the time and was copied separately. This manuscript includes the surgical section only. The majority of the instruments in our collection were made based on the descriptions and drawings in this work.

في خياطة الانف والشفه والاذن اذا تفرق اتصالها

عن جرح او نحو ذلك ○ اعلم انه متى حدث تفرق اتصال في احد هذه الاعضاء بنفس
فقل ما ينجع فيها العمل الا في بعض الناس فينبغي متى عرض لاحد شي من ذلك
فانظر ان كان الجرح طريا بدمه ان تجمع شفتي الجرح بالخياطة ثم تعالجه حتى
يبرا وان كان تفرق الاتصال قد افترق شفتاه وصار كل شق صحيحا فينبغي
ان تسلخ كل شق عن جلده الظاهر حتى يدما ثم تجمع الشفتين بالخياطة وتشدها
وتذر عليها السيازن واللبان مسحوقان وتضع من فوق الذرور لصقة من المرهم الدخلي
او غيره من المراهم الملحمه وتتركه مشدودا يومين او ثلاثة ثم تحله وتبدل
الدوا وتتركه حتى تنقطع الخيوط من ذاتها ثم تعالجه بالمرهم حتى يبرا وصفة الخياطه
ان تجمع تفرق الاتصال اما بالابر كما وصفنا في خياطه البطن واما تجمع التفرق بالخيط
كما عرفتك هناك

في اخراج العقد التي تعرض في الشفتين ○

قد يعرض لكثير من الناس في داخل شفاههم
اورام صغار صلبه تشبه بعضها حب الكرسنه وبعضها اصغر واكبر فينبغي
ان تقلب الشفه وتشق على كل عقدة وتعلقها بالصناره وتقطعها من كل جهة
ثم تحشو الموضع بعد القطع بزاج مسحوق حتى ينقطع الدم ثم يتمضمض بالخل والملح
ثم تعالج المواضع بما فيه قبض الى ان تبرا الجراحات ○

في قطع اللحم الزائد في اللثه ○

كثيرا ما ينبت
على اللثه لحم زايد تسميه الاوايل ابوليس فينبغي ان تعلقه بصناره او تمسكه بمنقاش
وتقطعه عند اصله وتترك المده تسيل او الدم ثم تضع على الموضع زاجا
مسحوقا او احد الذرورات القابضه المجففه فان عاد ذلك اللحم بعد العلاج

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TRANSLITERATION TABLE

ِ ، َ ، ُ **Short**	i, a, u	ص	ṣ
Long ا ، و ، ي	ā, ū, ī	ض	ḍ
ب	b	ط	ṭ
ت	t	ظ	ẓ
ث	ṯ	ع	ʿ
ج	ğ	غ	ġ
ح	ḥ	ف	f
خ	ḫ	ق	q

د	d	ك	k
ذ	ḏ	ل	l
ر	r	م	m
ز	z	ن	n
س	s	و	w
ش	š	ي	y