Mohammad Hashim Kamali · Osman Bakar
Daud Abdul-Fattah Batchelor
Rugayah Hashim *Editors*

Islamic Perspectives on Science and Technology

Selected Conference Papers

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Editors
Mohammad Hashim Kamali
International Institute
of Advanced Islamic Studies
Kuala Lumpur, Malaysia

Daud Abdul-Fattah Batchelor
International Institute
of Advanced Islamic Studies
Kuala Lumpur, Malaysia

Osman Bakar
Sultan Omar 'Ali Saifuddien Centre
for Islamic Studies (SOASCIS)
Universiti Brunei Darussalam
Bandar Seri Begawan, Brunei

Rugayah Hashim
Research Management Institute
Universiti Teknologi MARA
Shah Alam, Selangor, Malaysia

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Preface

The collection of papers that are featured in this book was presented at the International Conference on 'Developing Synergies Between Islam and Science & Technology for Mankind's Benefit', held at the International Institute of Advanced Islamic Studies (IAIS) Malaysia, Kuala Lumpur, on 1–2 October 2014.

The conference was formally opened by the former Prime Minister of Malaysia, Tun Abdullah Ahmad Badawi, and involved two keynote speeches, invited talks from eminent scholars, and talks by senior scholars, as well as some PhD candidates reporting on their research findings. The conference, consisting of both plenary and parallel sessions, included two open forums: one on bioethics and the other on the teaching and history of Islamic science. Presenter-authors were requested to contribute recommendations that could be taken up by governments, institutions, NGOs, and the public to hopefully ensure beneficial outcomes to sectors of humanity. The conference was closed with discussions on some of the important issues raised.

The conference objectives were:

- To promote a better understanding of the key issues related to religion in general, and to Islam in particular, in the current pursuit of scientific knowledge and in enhancing the well-being of humanity at large
- To address urgent ethical issues related to human biology/medical sciences and impacts on the living environment
- To investigate a more holistic faith-inclusive methodology for the teaching of science in Islamic educational institutions

Of a total of 37 papers presented, 26 were selected for inclusion in the present volume. The papers were wide-ranging in scope and organised under the following four clusters:

- Philosophy of Science, Cosmology and Emergence of Biological Systems
- Tawhidic Science – Principles and General Applications
- Tawhidic Science – Bioethics Applications
- Teaching and History of Science

The overarching theme of the conference included the need to investigate the epistemological and cosmological underpinning of science and technology (S&T) from an Islamic perspective, especially to understand the utilitarian aspects of S&T so as to better serve humanity. This conference aimed at addressing concerns that S&T should not, as appears to some today, be imperilling mankind's very existence, due to its misuse to serve powerful and elite interests. Ethical issues were addressed pertaining to the sound application of the Natural Sciences in serving humanity.

The deep metaphysical and cosmological issues regarding the role of science that can enhance understanding of our position in the 'grand scheme of things' were addressed as also the underlying substratum of current thinking that modern science already knows the answers and the fundamental questions are settled. The major role that religion and Islam, in particular, can play in this regeneration process was underlined. A comprehensive and holistic approach was to be sought that accorded with the principle of Divine Oneness (*Tawḥīd*) and the higher goals and purposes (*maqasid*) of Islam.

In what follows, I recapitulate some of the opening remarks that I made at the inaugural session of the conference in my capacity as the host and head of IAIS Malaysia.

> Whereas religion and ethics advocate restraint, the globalised world of scientific modernity and technological explosion with their secularist leanings are pushing humanity in the opposite direction, compelling us to raise the question: is there a crisis of values? Science, which is the motive power that propels technology, is the continuous process of interlinking observations and experiences into a coherent and logical structure that is then codified into a body of knowledge. Yet such knowledge remains open to challenge and modification through fresh observation, new experience and creativity of thought.
>
> The benefits of S&T to human well-being are undeniable. Yet the epistemology and method that propel scientific enquiry have followed a questionable trajectory that is blind to value and can advance both benefit and harm. The harmful effects of S&T are threatening human life and the health of its earthly habitat. The purity of the earth's natural environment is being compromised at an alarmingly rapid pace. Science and technology seem to have closed the doors to wisdom that one needs to know how best to make use of them.
>
> Our space is more crowded than ever before by a multitude of philosophical views and outlooks on how to understand religion and science and how to see the notions of progress, human well-being and ethics through their lenses. At one extreme we have the secular humanists arguing that modern science provides a necessary and sufficient basis for life and learning. From this viewpoint, religious worldviews are at best inconsequential and at worst an obstacle to human progress.
>
> Muslim scientists were successful in their contributions to science and civilisation when they maintained the nexus between existential reality and its metaphysical dimension, a theo-centric value order that guided their scientific enquiry, and their quest for knowledge and truth. Reality according to this outlook was not limited to the world of sensory experience but extended to the non-physical world, the *'alam al-ghayb*, as in the language and attestation of the Qur'an.
>
> The fruits of scientific enquiry and innovation in its Islamic vision belong to all of mankind. This is the inalienable implication of the principle of *Tawḥīd*, the Oneness of Being that runs deep in shaping the Islamic worldview and epistemology of knowledge. When S&T are informed by faith and ethics, they must serve the human interest and advance the efflo-

> rescence of a humane society and civilisation. Yet the prevailing scientific modernity subscribes to the view that science has no need for religion and views religion as the enemy of science. The Islamic view is that religion and science are truly in need of each other. This would explain why there is a need to present a credible critique of the epistemology of contemporary S&T. I believe that Islam's spiritual and intellectual resources and its holistic vision of scientific enquiry can make a significant contribution to the creation of a new scientific and technological culture that is focused on serving the interests of the whole of humanity.

Because of the diversity of themes and topics, there would be papers of interest to a large and broad group of academics and practitioners, from Islamic scholars and social scientists to physical scientists and engineers in a whole gamut of disciplines. This book should be of benefit to students, scholars and lay persons, Muslim and non-Muslims alike, who wish to obtain a more holistic understanding of Islam and science for humanity's benefit. Non-Muslims would be able to see the contributions Islam can make for the betterment of the world. It is also an important role for scientists of all persuasions to cooperate for the betterment of human society and the global environment.

A great deal of enthusiasm was generated in the conference discussions, especially during the concluding plenary session, on the importance of the chosen conference theme. Many prominent speakers recommended that this conference should be followed up and made into an annual event. It was also widely acknowledged that contributions to the natural sciences from the Muslim world were in short supply and need to be addressed. On behalf of IAIS Malaysia, I do hope we can actualise that recommendation to organise follow-up events on this or allied topics in the future. We are certainly working on beefing up one of the five of IAIS's research units on science, technology, environment and ethics from our own resources. For a follow-up and annual event, IAIS would need sponsorship and we plan to solicit outside support for this purpose.

It remains for me to thank Y.A.B. Tun Abdullah Haji Ahmad Badawi, former Prime Minister of Malaysia, for kindly accepting to officiate the opening of the conference and to record my appreciation and gratitude to the conference co-organisers, event partners and all those who supported IAIS Malaysia in this endeavour. We organised this event jointly with the International Islamic University Malaysia (IIUM), the Academy of Islamic Studies, Universiti Malaya (AIS-UM) and the Sultan Omar 'Ali Saifuddien Centre for Islamic Studies (SOASCIS), University of Brunei Darussalam with the support also of Universiti Teknologi MARA (UiTM) and the National Centre of Excellence for Islamic Studies, Griffith University, Australia. Having had the benefit of attending the conference sessions and reading the papers presented, I take this opportunity to commend the efforts and contributions of our learned speakers, authors and presenters whose deliberations and insights helped to make this international conference a success and also make the publication of the present volume possible.

Kuala Lumpur, Malaysia — Mohammad Hashim Kamali
April 2015

Contents

Chapter 26
Tracing the History of Astrolabe Inventions Across Civilisations

Mohd Hafiz Safiai and Ibnor Azli Ibrahim

Abstract This article surveys the history and application of astrolabes from before Islam's ascendance until the peak of the golden age of Islamic astronomy (*falak*). It also showcases the perpetuity of astrolabes as a multipurpose astronomical instrument used by a number of civilisations, Islamic and non-Islamic. The qualitative research method used involved document analysis and observations and the review of works on astrolabes by numerous scholars on its use in the field of astronomy. History and *falak* books were referenced to understand the use of this instrument in Islamic astronomy, which is currently known as *astrofiqh*. The astrolabe is a multipurpose analogue instrument for astronomical calculation and observation. The astrolabe invention became a symbol of ingenuity of Islamic scholars, and the concept behind it became a foundation for development of the latest digital astronomical instruments. Thus, knowledge of the astrolabe's development should be recorded to document one of the glories of Islamic civilisation while acting to inspire and enhance related fields such as the development of *astrofiqh* in Malaysia.

26.1 Introduction

The advancement of modern technology can be observed today in the various functions of the computer. Parallel to the advancement of modern technology, the computer has been modified and upgraded over time. Many people are unaware that the basic computer was invented and used a hundred years ago. The modern computer creates a digital and mathematic model system. Both of these features are used to follow a set of instructions in order to function as an automatic system. It is different from the analogue computer used a hundred years ago. An analogue computer created a system physically and required some human skill in order for it to

M.H. Safiai (✉) • I.A. Ibrahim
Department of Syariah, Faculty of Islamic Studies, Universiti Kebangsaan Malaysia, Bangi, Malaysia

Institute of Islam Hadhari, Universiti Kebangsaan Malaysia, Bangi, Malaysia
e-mail: hafizsafiai@ukm.edu.my; iabi@ukm.edu.my

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function. Such a type of computer in an earlier form manifested itself in what is known as the 'astrolabe'.

The word 'astrolabe' actually derives from the Greek word *asturlabun*, meaning 'star holder'. The astrolabe is an ancient analogue computer, which functioned to solve various problems involving astronomical calculation. Collins English Dictionary (2009) described an astrolabe as consisting of a graduated circular disc with a movable sighting device. The American Heritage Science Dictionary (2005) further defined an astrolabe as:

> An ancient instrument used widely in medieval times by navigators and astronomers to determine latitude, longitude, and time of the day. The device employed a disk with 360 degrees marked on its circumference. Users took readings from an indicator that pivoted around the center of the suspended device like the hand of a clock. The astrolabe was replaced by the sextant in the 18th century.

Random House Dictionary (2013) described the astrolabe as an astronomical instrument for taking the altitude of the sun or stars and for solutions of other problems in astronomy or navigation, used by Greek astronomers from about 200 BC and by Arab astronomers from the Middle Ages. Al-Farghani (2005) emphasised that the astrolabe was invented to observe and calculate the positions and movements of objects such as stars and planets in the celestial sphere. The astrolabe was an instrument commonly used in Islamic civilisation. It is unique in that it can still be operated and is useful even today. Through its invention as an analogue computer, Islamic civilisation has shown its ingenuity in astronomy and technical instrumentation, and such knowledge derived from the astrolabe should be preserved to ensure its capability is not lost.

26.2 Early Astrolabe History in Greek Civilisation

The history of the astrolabe invention includes aspects of technical and scientific knowledge which are elucidated in treatises and in practice. Knowledge of astronomy was sought for thousands of years by ancient civilisations, such as the Babylonian and Greek. According to Nallino (1911), during that particular period, astronomy, known as the knowledge of stars, was used for two main purposes: (1) to determine the movement of stars in order to calculate the seasons and wind directions and (2) to predict human fates (i.e. astrology). The history of the astrolabe began during the glorious Greek civilisation and was made famous by its scientific achievements. The knowledge of stereographic projections of celestial objects existed long before in the period of Apollonius (225 BC), but Hipparchus (190–120 BC) showcased his astronomical expertise regarding this knowledge through his theories related to astrolabe projections. According to Van der Waerden (1951), it is true that Hipparchus is known by his expertise in stereographic projection, but he did not invent the astrolabe. However, the existence of the contemporary astrolabe is based on his theories about the celestial realm.

The Hipparchus theory of stereographic projection has been used in the mechanised construction of such items as the anaphoric clock. According to Vitruvius (1981), a Roman writer and architect, this particular clock is the first machine invented and which functioned based on stereographic projection theory. The clock was built in Alexandria, Egypt, and was equipped with a set of stars moving around it showing the hours in a day. The technology then developed and spread to Salzburg, Austria and the northeast area of France. The role of Ptolemy[1] (90–168 CE) in astronomical research brought huge benefits to many of his contemporary scientists. One of his greatest works was *Planisphaerium*, which discussed horoscope instruments. Regarding the astrolabe invention, Ptolemy is considered the first to invent it. He finally managed this by using Hipparchus' theory of stereographic projection combined with his own work on the instrument.

Latham (1917) argued that the history of the astrolabe invention began in the period of Ptolemy, not Hipparchus. The astrolabe invented by Ptolemy was a simple version in regard to its construction and functions. Muslim scientists would later modify and enhance this instrument to provide more functions, not only to determine latitude and longitude.

The above view is supported by Ionides (1904) who agreed that invention of the astrolabe began with Greek civilisation. He opined that the concept of the astrolabe existed in the period of Hipparchus, yet the process of constructing the instrument only began in Ptolemy's period, and most astronomy historians agree that Ptolemy was the first to invent the astrolabe. The astrolabe, however, was modified by Muslim scientists according to the needs of Islamic civilisation, especially related to matters of Islamic worship, e.g. calculation of prayer times and determination of the *qiblah* (direction towards *Ka'abah*).

Neugebaeur (1949) analysed the history of the astrolabe invention and astronomical *zīj* (tables) in Greek civilisation. He rejected statements that the astrolabe had existed during the periods of Apollonius, Archimedes, Exodus or Hipparchus, prior to Ptolemy. He also opined that Ptolemy was the first person who invented the astrolabe around 150 CE. He believed that Ptolemy managed to invent it because of his excellent knowledge and skills about celestial objects. However, he did not deny that the knowledge and concept of the astrolabe existed before 150 CE.

In conclusion we accept that Ptolemy was the first person to invent a simple astrolabe. However, only after the instrument had been modified and enhanced by Muslim scientists did the astrolabe gain many more functions, especially for astronomical calculations.

[1] His real name was Claudius Ptolemaeus. He worked in Alexandria around 127–151 CE and was a highly regarded Greek scientist. Among his famous works was *Almagest*, which discussed the distance between earth-sun and earth-moon. A catalogue containing more than 1000 stars is attached to his book. *See* Fix (2008, pp. 50–51).

26.3 Astrolabe Development in Islamic Civilisation

Knowledge and ideas developed by scientists since the Greek civilisation continued to evolve until the time of the Islamic civilisation. Undeniably, some mathematical concepts in astronomy created by Greek scientists began to be studied and adopted by Muslim scientists during the eighth century through the translation of Sanskrit and Pahlavi texts (Pingree 1973). However, the wisdom of Muslim scientists led to science becoming more pragmatic by modifying and applying ancient astronomical theories and concepts. Theories and concepts which were modified or created by Muslim scientists are still being used today in solving certain astronomical problems.

Islamic civilisation is very extensive, covering a range of countries and cultures. Many contributions and successes were achieved by the advances of classical Muslim scholars. This exemplifies the benefits of Islam as a religion in that it is capable of developing a civilisation that elevates human dignity and intellect (Ibn al-Nadim 1994). During the Abbasid Caliphate, scientific and technological fields of knowledge received much attention. Many Greek works were translated into Arabic, covering various fields of science, including astronomy, astrology and the invention of the simple astrolabe. The astrolabe was introduced and developed in the first eight centuries of Islamic civilisation.

This development partly resulted from the efforts of the ‘Abbasid Caliph al-Ma’mun, in advancing uses of the astrolabe in daily life. Further, he utilised the astrolabe as a tool in administrating Muslim worship practices. The close relationship between Islam and astronomy opened up opportunities for the invention and further development of various functions. To calculate the prayer times and determine the direction of Mecca – both challenging problems – requires good knowledge and high skills in astronomy. Through use of the astrolabe, the problems related to prayer times and *qiblah* direction could be resolved more quickly and easily (Hayton 2012).

For centuries, Arabic, Persian and Hebrew scientists attempted to write and publish systematic treatises on the use of the astrolabe so that it would be easily learned and understood. Beginning in the ninth century, treatises on the astrolabe were published, such as by Masha’Allah, a Jewish scientist from Basra. However, his original pamphlet written in Arabic has been lost. Fortunately, its translation in Latin is extant and readable (Lorch 2013).

Among traditional works related to the astrolabe which still survives is one written by al-Khwarizmi. He authored two short treatises concerning the development and functions of the astrolabe. Other traditional works on the astrolabe, which survive, belonged to ‘Ali ibn ‘Isa and Ahmad ibn Muhammad ibn Kathir. Aside from writing, ‘Ali ibn ‘Isa was also involved in observations conducted in Baghdad and Damascus under the supervision of Caliph al-Ma’mun. In the early part of the eleventh century, the Persian scientist al-Biruni, famous for *The Book of Instruction in the Elements of the Art of Astrology*, discussed the construction, parts and functions of the astrolabe (Sarton 1935). Muslim scientists also managed to invent a newly enhanced astrolabe. The astrolabe enhancements were then very highly respected and admired. The most commonly used astrolabe as a navigational instrument was the mariner's astrolabe. Many instrument makers began to learn and develop skills and build businesses related to the astrolabe.

In the process of enhancing the astrolabe, there were no strict guidelines for designing and decoration. Decoration of the astrolabe was usually based on its maker's creativity. Among the common elements was placement of the maker's name and signature on the astrolabe. Some liked to put information about the date and place where the astrolabe had been made. If there was such information, it was then easy to detect the origin of the astrolabe in order to identify and understand the relationship between the manufacturer, his environment and the specific technology.

Ibn al-Zarqali is among the Muslim scientists who excelled in the development of the astrolabe. He was famous for his skill in creating tools and had invented his own form of astrolabe (Kahhalah 1972). He also created *ṣafīḥa* as a refinement incorporated within the astrolabe. *Ṣafīḥa* is an Arabic translation of the English word 'tympan'. It consists of the local latitude of a place with the altitude and azimuth and also functioned as a star map (Hill 1993). Ibn al-Zarqali also wrote a book describing the astrolabe which was later translated by Western scholars into Latin (Ahmad 2003). He is known for his skills of observation, and he was very skilled in determining the time of the eclipse and created a compass to determine the distances between the moon and the earth and between the stars and the sun. He also compiled the Toledan Tables which were derived from Ptolemy and al-Khwarizmi (Samso 1994).

The effects of technical innovation from Islamic civilisation can also be seen in India. Scientists, who were much-travelled, such as al-Biruni, introduced the astrolabe to India. In the fourteenth century, Sultan Firuz Shah Tughluq funded the further development of the astrolabe. In the meantime, the Sanskrit treatise regarding the astrolabe, *Yantraraja*, meaning 'king of astronomical instruments', was written by Mahendra Suri, a monk (Sarma 1999). According to Sarma (2000), in the middle of the sixteenth century, the uses of the astrolabe expanded into government administration. The new ruler acknowledged the astrological approach in managing and administering the country's problems and introduced it for its political value. Among the well-known Mughal rulers at that time was Humayun. Under his rule, Lahore (now in Pakistan) became a manufacturing centre of the Indo-Persian astrolabe (Erskine 1995). One of the astrolabe makers, Diya' al-Din Muhammad, constructed more than 30 astrolabes from 1645 to 1680 CE, and his family produced more than 100 pieces (Sarma 2009).

Ohashi (1997) observed that Lahore is not the only place which produced astrolabes in India. Jaipur also became an important manufacturing centre. This was the ultimate achievement gained by the contemporary ruler Maharaja Sawai Jai Singh II who promoted expansion of scientific and technological knowledge. In addition to this, the emperor wrote a book discussing the astrolabe. According to Soonawala (1952), the instruments in India, especially in Jaipur, were famous for their distinctive size which was appropriate for its latitude at 27° North. The emperor was also responsible for the construction of five astronomical observatories in India.

26.4 Early Modern History of Astrolabe in Europe

The astrolabe was introduced to Spain through Cordoba, the Umayyad capital. Scholars across Spain quickly took the opportunity to learn and understand the astrolabe. Beginning in the late tenth century, the astrolabe and treatises related to its uses had been produced by Muslims in Spain. At first, all these astrolabes were similar to those found in other countries. On the initiative of the astrolabe makers in Spain, they began to modify the standard pattern to differentiate themselves from other manufactures, highlighting the distinctive features of Spain (Evans 1998). For example, they changed the language used. Originally, astrolabes were produced in Arabic, but this was later changed to Latin. This aimed to facilitate a better understanding of the astrolabe by visiting scholars who came to Spain to learn about the knowledge of Islamic and Greek civilisations. Through translation, they brought back this knowledge about the astrolabe to their countries. Translated items included the names of the months and zodiac constellations. The ready availability of these is considered one of the major factors that accelerated the spread of the knowledge and applications of astrolabe technology throughout Europe (Gibbs and Saliba 1984; Saliba 2007). From the eleventh until the thirteenth century, most astrolabes in Europe were brought in from Spain.

Beginning in the fourteenth century, astrolabe knowledge was developing rapidly in Europe. A set of guidelines for astrolabe construction and uses was first published and became one of the most important teachings in European universities. Chauser,[2] an English writer, opined that he should send his son to Oxford University to study the astrolabe and its treatises. Acknowledging the importance of the astrolabe at that time, he had written a guide for using the astrolabe, entitled *A Treatise on the Astrolabe* (Chauser 1391).

The knowledge of the astrolabe was not limited to universities only but was even more popular among the royals. According to Gibbs and Saliba (1984), rulers throughout Europe began to collect, study and use the astrolabe as a support tool in better managing and administering their countries. Among the purported regular functions of the astrolabe used by them was to determine the best time to declare war and attack their enemies. The astrolabe was correspondingly used to determine the best time to end a war and subsequently became a symbol of peace. According to Glick et al. (2014), the sixteenth century was when the astrolabe reached its ultimate height of development in Europe. Many treatises and reading materials were published then in small volumes and low prices for public reading. They emphasised the principles of astrolabe uses such as to determine the time and the zodiacal constellations. Better-quality larger treatises, which included images, were also published. These higher-quality treatises were equipped with more details including on its invention and the diversity of its functions. Several series of these treatises were printed and translated into Latin for a wider market.

[2] Geoffrey Chaucer was an English philosopher born in 1343 in London. He was admired throughout mediaeval Europe. He was also active as a writer and astronomer. See Rudd (2001, pp. 1–5).

The sixteenth century experienced the rapid development of astrolabe makers in Europe. Germany was a country that practised traditional iron work and became a centre for the manufacture of instruments in the late fifteenth century. As copper prices were cheaper in Germany than other countries in Europe, Germany could monopolise the manufacture of instruments, especially the astrolabe (Turner 1994). According to King (1999), one of the famous astrolabe makers at that time was Georg Hartmann. In his workshop, he produced a large number of instruments in accordance with desired specifications and patterns. He was also the first person who made the astrolabe from paper and wood.

In the seventeenth century, the process of manufacturing astrolabes slumped dramatically in Europe. By the early eighteenth century, astrolabe manufacturing activities almost ceased in line with the invention of higher technology instruments, such as the sextant around 1730. Scholars eventually became more interested in collecting astrolabes as antiques. Some, however, having a historical interest of instruments, collected astrolabes to be stored and maintained (Gibbs and Saliba 1984).

The world's largest collection of astrolabes is at the Museum of the History of Science located in Oxford, United Kingdom. A number of these astrolabes sourced from three continents, covering the period from the ninth to mid-seventeenth century, are illustrated in Appendix 1. As a department at the University of Oxford, the museum's role is to maintain and allow historians to study the artefacts and to facilitate their public exhibition. The museum carries approximately 20,000 historical scientific instruments covering a wide range of fields, such as mathematics, optics, chemistry, philosophy and medicine – from the Middle Ages until the twentieth century. The museum also displays manuscripts and pictures for historical reference.

26.5 Conclusion

During the extensive period of Islamic civilisation, knowledge of the astrolabe was acquired, developed, updated and expanded from India to Spain. With the rapid development of the astrolabe in the Muslim world by scholars and craftsmen, many Latin scientists came to Spain to learn and undergo training in its valuable uses. Once they learned and mastered this knowledge, they would return home and bring along the instrument and related astrolabe texts. They taught and developed further this knowledge outside of Spain. These efforts created many skilled European scientists knowledgeable in astrolabe technology. This is proved by the rapid development of astrolabe technology in Europe in the sixteenth century as well as being an incentive for the creation of other astronomical instruments in the West. The Muslim world continued to produce astrolabes for a further 200 years. Among the famous Muslim astrolabe makers was the firm of Muhammad bin Ahmad al-Battuta, who still produced astrolabes until the eighteenth century in Morocco. The concepts and ideas of the astrolabe invention, which was strongly enhanced by the early Muslim scientists, helped the advance of modern instrumentation technologies until today.

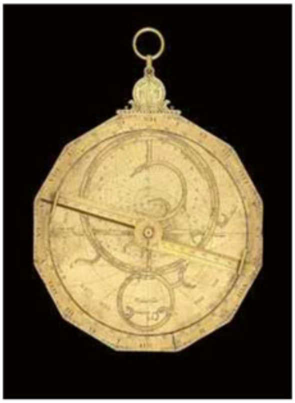
Appendix 1

Syria (end of 9th century)

Isfahan (1221)

Egypt (1282)

Spain (1300)



Germany (1585)

India (1647)

Source: Museum of the History of Science, Oxford University, Oxford, UK. Accessed from http://www.mhs.ox.ac.uk/collections/

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