ASTROLABE AS PORTAL TO THE UNIVERSE, INVENTIONS ACROSS CIVILIZATIONS

Mohd Hafiz Safiai
Department of Syariah, Faculty of Islamic Studies & Institute of Islam Hadhari, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

Ibnor Azli Ibrahim
Department of Syariah, Faculty of Islamic Studies & Institute of Islam Hadhari, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

Ezad Azraai Jamsari (Corresponding Author)
Department of Arabic Studies and Islamic Civilization, Faculty of Islamic Studies, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

Badlihisham Mohd Nasir
Faculty of Islamic Civilization, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia

Md Yazid Ahmad
Department of Syariah, Faculty of Islamic Studies, Universiti Kebangsaan Malaysia 43600 UKM Bangi, Selangor, Malaysia

ABSTRACT

This article overviews the history of astrolabe invention from early Greek astronomy until the peak of the golden age of Islamic astronomy (al-falaq). It also highlights the importance of the astrolabe as the key to learning about the universe, an instrument which outlasted civilisations, both Islamic and non-Islamic, as the key to learning about the Universe. The research method used is qualitative and involved document analysis and observations of works on astrolabes done by numerous scholars in order to obtain data on use of this device in astronomy. History and Islamic astronomy sources were referenced to understand the significant use of this device. The astrolabe is a perpetuity analogue device for astronomical calculation and observation. The concept behind the astrolabe became a foundation for development of the latest digital astronomical devices and it became a symbol of the inventiveness of Islamic civilization scholars since the Muslims used it the longest. Thus, knowledge of the astrolabe’s evolution should be documented as one of the glorious achievements of the Islamic civilisation in efforts to galvanize and intensify related fields such as the development of Islamic astronomy in Malaysia.
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 computer made a hundred years ago, known as the analogue computer. An analogue computer created a physical system and required some human skill in order for it to 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.

In addition, 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) emphasized 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 the Islamic civilization. It is unique in that it can still be operated and useful even today. Through its invention of the analogue computer, the Islamic civilization 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.

2. LITERATURE REVIEW

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 civilizations, 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 civilization and was made famous by its
Mohd Hafiz Safiai, Ibnoor Azli Ibrahim, Ezad Azraai Jamsari, Badlihisham Mohd Nasir and Md Yazid Ahmad

scientific achievements. The knowledge of stereographic projection of celestial objects existed long before in the period of Appolonius (225 B.C.), but Hipparchus 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 for 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.

![Figure 1 Concept of Stereographic Projection.](image1)

![Figure 2 Principle of Stereographic Projection.](image2)

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 was the first machine invented and functioned based on the 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 in astronomical research around 150 BC 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 simpler version of its contemporaries in regards to its construction and functions. Scientists of the Islamic civilization would later modify and enhance this instrument to provide more functions, not only to determine latitude and longitude. Ptolemy real name was Claudius Ptolemaeus. He worked in Alexandria around 127 to 151 C.E.
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 (Fix, 2008).

![Figure 3 Lines of Projection](image)

![Figure 4 Celestial Stereographic Projection](image)
The above view is supported by Ionides (1904) who agreed that invention of the astrolabe began with the Greek civilization. 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 the Islamic civilization, especially in relation to matters of Muslim worship, e.g. calculation of prayer times and determination of the qiblah (direction towards Kaaba).

Neugebauer (1949) analysed the history of the astrolabe invention and astronomical zij (tables) in the Greek civilization. He rejected statements that the astrolabe had existed during the periods of Apollonius, Archimedes, Eudoxus or Hipparchus, prior to Ptolemy. He also opined that Ptolemy was the first person who invented the astrolabe around 150 B.C. 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 BC.

In conclusion we accept that Ptolemy was the first person who invented the astrolabe. Nevertheless, the astrolabe by Ptolemy was just a simple version regarding its functions. Only after the instrument had been modified and enhanced by scientists of the Islamic civilization did the astrolabe gain many more functions and could be used widely for many mathematical problems, especially astronomical calculations (Safiai et al., 2016).

3. RESULT AND DISCUSSION

3.1. Influence of the Islamic Civilization in the Development of Astrolabe

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

The Islamic civilization was very extensive, covering a range of countries and cultures. Many contributions and successes were achieved by the advances of classical Muslim scholars. This proves the benefits of Islam as a religion in that it is capable of developing a civilization that elevates human dignity and intellect. During the ‘Abbasid caliphate, scientific and technological knowledge received a lot of attention. Many Greek works were translated into Arabic, covering various fields of science, including astronomy, astrology, and the invention of the astrolabe. Astrolabe was introduced and developed in the first eight centuries of the Islamic civilization. From that moment, astrolabe has been an ultimate instrument in both observation and calculation where it has been used by Muslim astronomer in the observatory (Ibrahim et al., 2012; Mujani et al., 2012; Safiai et al., 2014; Ibrahim & Safiai, 2014; Ibrahim et al., 2015).

This development partly resulted from the efforts of the ‘Abbasid caliphs, al-Ma’mun, in advancing the uses of the astrolabe in daily life. Further, he utilized 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. Calculation of prayer times and determination of the direction of Mecca – both
challenging problems – require good knowledge and high skills in astronomy. Through the use of the astrolabe, the problems related to prayer times and qibla 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 learnt and understood. Beginning in the 9th century, treatises on the astrolabe were published, such as by Masha Allah, a Jewish scientist from Basra. However, his original pamphlet written in Arabic was lost. Fortunately, its translation in Latin is extant and readable (Lorch, 2013).

Among traditional works related to the astrolabe which is extant, is one written by al-Khwarizmi. He authored two short treatises concerning the development and functions of the astrolabe. Other extant traditional works on the astrolabe 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 11th 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. Many instrument-makers began to learn and develop skills related to the astrolabe, managing to successfully sustain their businesses for many years.

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 maker, his environment, and the specific technology. Ibn al-Zarqali was among the Muslim scientists who excelled in 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 safiha as a refinement incorporated within the astrolabe. Safiha 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).

Figure 5 Projection of the Altitude Circles on the Astrolabe
Mohd Hafiz Safiai, Ibnor Azli Ibrahim, Ezad Azraai Jamsari, Badlihisham Mohd Nasir and Md Yazid Ahmad

Figure 6 Principle of Safiha from the Astrolabe by Ibn al-Zarqali

Ibn al-Zarqali also wrote a book describing the astrolabe which was later translated by Western scholars into Latin (Ahmad, 2003). He was 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 impact the golden age of the Islamic civilization can be seen in India. Much travelled scientists, such as al-Biruni, introduced the astrolabe to India. In the 14th 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 16th 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 Mughul rulers at that time was Humayun. Under his rule, Lahore (now in Pakistan) became a manufacturing centre of the Indo-Persian astrolabe. 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 was not the only place which produced astrolabes in India. Jaipur also became an important centre for their manufacture. 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°. The emperor was also responsible for the construction of five astronomical observatories in India.

3.2. Early Modern Production of Astrolabe in Europe
The astrolabe was introduced to Spain through Cordova, the Umayyad capital. Scholars across Spain quickly took the opportunity to learn and understand the astrolabe. Beginning in the late 10th 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 Muslim
countries. On the initiative of the astrolabe makers in Spain, they modified the pattern and attempted to differentiate themselves from other manufacturers, 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 civilizations. Through translation, they brought back this knowledge about the astrolabe and spread it throughout 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 the astrolabe technology throughout Europe (Gibbs & Saliba, 1984; Saliba, 2007). From the 11th until the 13th centuries, most European astrolabes were brought in from Spain.

Beginning in the 14th 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 universities throughout Europe. Chaucer, 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, 1931). Geoffrey Chaucer was an English philosopher born in 1343 in London. He was admired throughout medieval Europe. He was also active as a writer and astronomer (Rudd, 2001).

Knowledge of the astrolabe was not limited to only universities, but was even more popular amongst the royals. According to Gibbs and Saliba (1984), rulers throughout Europe began to collect, study and use the astrolabe as a support tool to better manage and administer 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, Livesey and Wallis (2014), the 16th century was when the astrolabe reached its ultimate height in Europe. Many treatises and reading materials were published then in small volumes and at low prices for public reading. They emphasized the principles of astrolabe uses such as to determine the time and the zodiacal constellations. Better quality larger treatises with images were also published. These higher quality treatises were equipped with more details including its invention and the diversity of functions. Several series of these treatises were printed and translated into Latin for wider markets.

The 16th century showed the rapid development of astrolabe makers in Europe. Germany was a country that practiced traditional iron work and became a centre for the manufacture of instruments in the late 15th century. As copper prices were cheaper in Germany than other countries in Europe, Germany could monopolies 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 astrolabe from paper and wood.

In the 17th century, the process of manufacturing astrolabes slumped dramatically in Europe. By the early 18th century, astrolabe manufacturing activities almost ceased, with the invention of higher technology instruments, such as the sextant around the year 1730. Scholars eventually became more interested in collecting astrolabes as antiques. Some scholars however, having a historical interest in instruments, collected astrolabes to store and maintain them (Gibbs & Saliba, 1984).
The world’s largest collection of astrolabes is at the Museum of the History of Science located in Oxford, United Kingdom. As a department at the University of Oxford, the museum’s role is to maintain and allow historians to study the artifacts 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 20th century. The museum also displays manuscripts and pictures for historical reference.

4. CONCLUSIONS
During the Islamic civilization, 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 further developed this knowledge outside of Spain. These efforts created many skilled European scientists knowledgeable in astrolabe technology. This is proven by the rapid development of astrolabe technology in Europe in the 16th century, which in turn stimulated 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, which continued to produce astrolabes until the 18th century in Morocco. The concepts and ideas of the astrolabe invention, which was strongly enhanced by the early scientists of the Islamic civilization, helped in the advancement of modern instrumentation technologies until today.

ACKNOWLEDGEMENT
This study is financed by the Research Group of Astrofiqh and Cosmofiqh (ANCOR, GUP-2016-018; GUP-2015-013), UKM; the Research Group of the Nasrid Studies (GUP-2015-011), UKM; the Research Group of Arabic Culture and Islamic Civilization (KUKAPI, DPP-2015-067) UKM; and the Research Group of West Asian Studies (AKRAB, DPP-2015-085).

REFERENCES
Astrolabe as Portal to the Universe, Inventions across Civilizations


http://www.iaeme.com/IJCIET/index.asp 618 editor@iaeme.com


[39] Abdul Ghofur . The Implications of Democratization Towards Deformalization of Islamic Law in Indonesia: Study on Abdurrahman Wahid’s Thoughts. International Journal of Mechanical Engineering and Technology , 8(6 ), 2017, pp. 70 –84
