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Observing Sun's Altitude During Transit Using Astrolabe as a Teaching Aid in Astrofiqh

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Abstract
This article discusses the accuracy of astrolabe in obtaining sun's altitude data during transit. Astrolabe is an ingenious astronomical instrument which was created both to observe and calculate the coordinates of celestial objects such as stars and planets thousands of years ago. However, various creations of modern instruments made astrolabe to be considered as inaccurate and eventually getting forgotten. Thus, this study attempts to analyses the data of sun's altitude during transit obtained by astrolabe. This is a qualitative study with technical features by adopting document analysis, observation, and comparison analysis approaches. The data analysis process has been conducted by comparing the data obtained by astrolabe and the official data retrieved from Department of Survey and Mapping Malaysia (JUPEM). The finding shows that astrolabe can be used both for observation and calculation purposes and it is still relevant for today's use. This study is quite important to be carried out to create awareness on the importance of ancient astronomical instruments and at the same time to commemorate the golden ages of the Islamic civilization which incorporated hundreds of years of Islamic science, technology, engineering, and mathematics.
Keywords: Astrolabe, Islamic Astronomy, Astrofiqh, Cosmofiqh, Sun's Transit

Introduction
In line with the development of today's modern technology, computers have become a necessity in people's daily lives. In fact, computer usage has been around much longer than most people think and is known as astrolabe. Astrolabe is analogous and manual, but its diverse usage continued for ages and made it a very useful and popular device back then. However, after about a thousand years, the advent of specialized instruments that replaced the various functions of the astrolabe caused a decline in its popularity as a device. Modern computers generate mathematical model systems in digital form that is manipulated to operate automatically according to a setting. While astrolabe produces an analogous model

system and is manipulated by the observer to get the data concerning the movement of celestial objects.

Research on Astrolabes: A Literature Review

This study also conducted several past studies related to astrolabes in the Malaysian context such as 'Astrolabe as Portal to Universe, Inventions Across Civilisations' by Safiai et al (2017), 'The Continuity of Astrolabe as a Multipurpose Astrofiqh Instrument' by Safiai et al (2016), and 'Tracing the History of Astrolabe Inventions Across Civilisations' by (Safiai & Ibrahim, 2016). Most of the previous studies only focused on the history of the development of astrolabes creation. Furthermore, the studies that discussed astrolabes are very limited. Thus, this study has referred to several past studies that discussed astrolabes internationally for additional information such as 'The Astrolabe: Mechanism for reading the stars' by Aterini (2019), 'Astrolabe: Curating, linking, and computing astronomy's dark data' by Heidon et al (2018), 'Star taker: Art, science and mathematics in an astrolabe from fourteenth-century Spain' by Bentley (2018), and 'Transmedial technics in Chaucer's Treatise on the astrolabe: Translation, instrumentation, and scientific imagination' by (Mitchell, 2018). This study found that astrolabe education is happening very rapidly in foreign countries, especially Europe thus increasing the progress of the knowledge compared to other countries. Therefore, this study will examine the writings related to astrolabes in the Malaysian context.

Through the creation of astrolabes as an analog computer, Islamic civilization has shown its glory in the field of astronomy and efforts on researching related to astrolabes should be carried out continuously so that the knowledge does not simply disappear. A concerted effort by various parties such as the government, academics and students should be built and created to prevent one party from clapping. Therefore, this study was conducted to identify the accuracy of astrolabes in their insight's activities and the appropriateness of their current use in Malaysia. Such studies should be carried out to help improve the progress of astronomy knowledge in Malaysia, thus restoring the glorious history of Islamic civilization in the eyes of the world.

The Concept of Astrolabe

Before learning about the use of astrolabe, some basic knowledge about the concept of astrolabe creation needs to be enlightened first, such as:

a) Celestial Sphere (al-Kurrat al-Samawiyyah)

Celestial sphere is an imaginary sphere or imagination of the sky depicted by observers on earth. The concept of the sphere has been applied for thousands of years by observers on earth by imagining that the earth is in the center of the solar system and all the celestial objects revolve around it, including the sun (Millar, 2006: 5). Through this spherical rotation, observers on earth can see the changes in movement and the position of the celestial objects as if they were under a dome. The use of this celestial sphere concept has enabled a variety of studies related to the universe to be carried out easily and practically. In addition, this sphere can also be used as a sign of natural phenomena such as the exchange of day and night, change of seasons and so forth (Warm, 2010: 10).

Celestial sphere is imagined as a very large and wide size that can cover stars with millions of light years away from the earth. Like the earth, celestial sphere also has its own poles. In the design of celestial sphere concept, a straight line of the earth's pole is projected to the sky and the line is considered as the pole of the celestial sphere parallel to the earth's poles. This can also be seen from the position of the celestial equator which is parallel to the earth's equatorial line (Kaler, 2002: 18-20).

From the earth, observers can only see some part of the sky, that is a part of the sky that sits on the horizon at any time either during the day or night. In fact, sky objects are always circulating and moving alongside the rotation of the earth and this phenomenon causes sunrise and sunset every day, as well as the stars occur in the sky every night (Kar & Chandel, 2009: 19). Due to their same cycle, observers on earth can identify and record the movement and position of any object in the celestial sphere. In order to identify the actual position of a star in the sky, observers only need to acquire two coordinates, which are the Right Ascention (Suuud Mustaqim) and the declination (Mayl) (Chun-Hao et al., 1990).

b) Ecliptic (Da'irat al-Syams)

The sun's movement around the earth seen in the sky all year long is known as the sun's path. Through the concept of celestial sphere, the sun is seen revolving around the earth from east to west. In fact, the sun's path is the trajectory of the earth's orbital movement in the celestial sphere. As the sun circulates on its path throughout the year, its circulation goes past 12 clusters of stars known as zodiac constellations. In addition to the sun, planets are also seen circulating past the same constellations in the celestial sphere. This phenomenon occurs as the planets revolve around the sun on a plane that is mostly the same as the plane travelled by the earth (McBride & Gilmor, 2004: 23-24).

The sun's path in the celestial sphere is not exactly spherical but a bit oval and this shape is called ellipse. Therefore, there are two conditions that occur throughout the year regarding the position of the distance between the earth and the sun namely perihelion and aphelion (Hanslmeier 2007:131). Perihelion (al-Hadid) means that the sun is in the nearest position to the earth while aphelion (al-Auj) is when the sun's position is the most distant from the earth. These two words were taken from the Greek, in which *helios* means sun, *peri* means near and *apo* means far (Pasachoff & Peterson, 2015: 18).

When the sun is at its nearest to the earth, the distance between those two has been identified as 147 million km, while the distance between the earth and the sun when the sun is the farthest is 152 million km (Barry & Hall-McKim, 2014: 179). In addition, when perihelion occurs, the earth rotates above its axis at a very high rate than normal, while when aphelion occurs, the earth rotates quite slowly than the usual speed. This also happens to other planets in our solar system. Therefore, each planet has a particular period where the sun is at the nearest and farthest depending on the size of the planet's orbit (Hamilton, 2007: 7).

c) Tropic (al-Madar)

The change of seasons occurs due to the inclination of the earth's axis by 23.5° of the equator line and 66.5° of the orbital planes. The slightly sloping position of the earth while revolving around the sun causes the places facing the sun to experience summer while the other side experience winter. The phenomenon of seasons occurs four times over a year, the spring and autumn equinox, and summer and winter solstice. This phenomenon only occurs in world's temperate climate areas in the Northern Hemisphere and Southern Hemisphere such as Canada, United States of America, China, Japan, and European countries (Archambault, 2009: 115).

The earth is divided into five major lines which are the Arctic Line, the Tropic of Cancer Line, the Equator Line, the Tropic of Capricorn Line and the Antarctic Line. The Arctic and Tropic of Cancer rows both are situated in the Northern Hemisphere, while the Antarctic and

Tropic of Capricorn lines are in the Southern Hemisphere. The equator line is in the middle, dividing the earth into two parts namely the Northern Hemisphere and the Southern Hemisphere (Fernandez, 2013: 35). The spring equinox or also known as vernal equinox (al-Itidal al-Rabii) occurs when the sun is exactly above the equator line, which is 0°. Starting on 21st March each year, the northern hemisphere experience spring season while the southern hemisphere experiences fall season. At this point, the northern hemisphere and the southern hemisphere experience the same length of day and night (Jackson, 2002: 1).

Furthermore, the summer solstice (al-Inqilab al-Sayfi) occurs when the sun is just above the Tropic of Cancer line, which is 23.5° N. The phenomenon that occurs every 21st June during the year causes the Northern Hemisphere to experience summer while South Hemisphere has winter. At this point, the length of day in the Northern Hemisphere is longer and the length of night in the Southern Hemisphere is longer. This phenomenon causes the north pole to experience six months of day and the south pole experiences six months of night throughout the year (Martin, 2016: 274).

With the end of the summer solstice, then the autumn equinox (al-Itidal al-Kharifi) starts. This phenomenon occurs when the sun returns directly above the Equator line, which is 0°. This phenomenon begins on 23rd September each year and causes the Northern Hemisphere to experience autumn while the Southern Hemisphere experiences spring. At this point, the northern hemisphere and the southern hemisphere are back to the same length of day and night. During autumn equinox, the leaves will dry up and fall from the branches. Unique scenery can be seen when trees begin to dry out as if they were about to die. But the truth is during this time, plants are getting ready for winter (Pidwirny, 2017: 27).

Finally, the winter solstice (al-Inqilab al-Syatawi) occurs when the sun is exactly above the Tropic of Capricorn line, which is 23.5° S. The sun's position in the celestial sphere begins on 22nd December each year causing the Northern hemisphere to experience winter while Southern Hemisphere experience summer. Additionally, the length of the night in the Northern Hemisphere is also longer than the Southern Hemisphere while the opposite is in the Southern Hemisphere with a longer day than the Northern Hemisphere (Seeds & Backman 2007: 19-20). At the same time, this phenomenon causes the north pole to experience six months of night and the south pole undergoes six months of day depending on the position of the earth while rotating on its axis. If the Northern Hemisphere is experiencing winter, the Arctic will not receive sunlight that it is always night there and so on otherwise in the South Pole (Philander, 2012: 1246).

d) Local Sky (al-Sama' al-Mahalliy)

In the local sky system, there are several elements that need to be learned and understood. This is important since astrolabe functions are based on the knowledge regarding the local sky system of the observer's location. For example, during sky observation, observers can only see part of the sky while the rest are obscured due to geographical conditions and hidden under the horizon. The first thing that an observer should know is the horizon (al-Ufuq). The horizon is a line that looks as though it separates the sky and the earth. The horizon is also known by some Malaysians as *kaki langit* (skyline).

The horizon is divided into two categories namely true horizon and visible horizon. True horizon (al-ufuq al-haqiqi) cannot be seen by naked eyes. Azhari (2005: 228) defined true horizon as follows:

A flat plane projected from the centre of the earth, perpendicular to the oval line in such a way that it splits the earth and the sky ball into two sections with equal size, where the top part is within the range of 90° from the horizon to the zenith and the lower part is within the range of 90° from the horizon to the nadir. In the height calculations of a celestial body, it is calculated starting from this horizon. While the visible horizon (al-ufuq al-mar'i), according to Khazin (2004:86), is a line that brings together the earth and the sky that can be seen by naked eyes. Usually, the horizon can be seen in coastal areas or wide plain areas. Therefore, all official observatories in Malaysia were built on the seafront for a wide horizon view without being obstructed by any obstacles.

e) Zenith (Samt al-Ra's) and Nadir (al-Nadhir)

Zenith refers to one of the highest points located on celestial sphere. Zenith is located right above the head where the observer is at 90° from the horizon. According to The Columbia Electronic Encyclopedia (2012), zenith is a point of intersection between celestial sphere and a straight line projected from the observation point to the sky. While nadir refers to one of the lowest points located on celestial sphere. Contrary to zenith, nadir is directly below the foot where the observer is in the range of -90° from the horizon. Thus, the distance between zenith and nadir is 180°.

f) Meridian Line (Khat al-Zawal)

According to Hutton (1815: 44), the word meridian comes from the Latin word, *meridius* which means noon. This is because when the sun is at the meridian line of an area it passes, the area will experience the middle of the day (Preston & Tottle, 1969: 9). To be precise, meridian is a line on celestial sphere that transcends zenith and nadir and connects the celestial north pole to the celestial south pole. Meridian also divides celestial sphere into two equal parts, the northern hemisphere, and the southern hemisphere (Waldron, 2013: 30).

To better understand, the meridian line is drawn as the resulting line when the observer's arm is raised forward facing the north and swirled backward over the observer's head to face the south. Therefore, the meridian line of a person differs from the meridian line of another person. But only if the two observers are on the same longitude line that they will have the same meridian line.

Astronomers set an area known as Greenwich, located in London, as the Prime Meridian (Khat al-Zawal al-Awwal). With that, the meridian line in Greenwich represents the Prime Meridian line which is defined as 0° (Dolan, 2003: 5). If a great number of observations is made from the same meridian line, this will allow for a complete map of night sky stars to be produced by taking into account the star changes that occur throughout the year on the same meridian (Ariel & Berger, 2006: 96).

Result and Discussion: The data comparison analysis of sun's altitude during transit

Through this study, astrolabe was used to obtain the data of solar altitude during transit. The data generated using astrolabe has been compared to the official data issued by the Department of Survey and Mapping Malaysia (JUPEM). This study uses the coordinates of Islamic Centre of Universiti Kebangsaan Malaysia, Bangi, 2.9° N 101.8° E as an observation station. Besides, this study conducted observations in March as the beginning of spring equinox during that month. As discussed earlier, the sun was at the top of the Equator line, making it an ideal time for observation activities. The following are the results which have been produced:

Table 1
The Differences in the Degree of the Sun's Altitude During Transit

Date	Transit Time	Sun's Altitude Obtained from JUPEM's	Sun's Altitude Obtained by Astrolabe	Difference (Degree °)
01 March 2019	13:26	79° 39 13	78°	-1
02 March 2019	13:26	80° 02 02	78°	-2
03 March 2019	13:26	80° 24 56	79°	-1
04 March 2019	13:26	80° 47 54	79°	-1
05 March 2019	13:26	81° 10 54	79°	-2
06 March 2019	13:26	81° 33 57	80°	-1
07 March 2019	13:26	81° 57 46	79°	-2
08 March 2019	13:26	82° 20 06	80°	-2
09 March 2019	13:26	82° 43 10	81°	-1
10 March 2019	13:26	83° 06 12	81°	-2
11 March 2019	13:25	83° 30 41	82°	-1
12 March 2019	13:25	83° 53 50	83°	0
13 March 2019	13:23	84° 18 19	83°	-1
14 March 2019	13:23	84° 41 34	84°	0
15 March 2019	13:23	85° 04 42	84°	-1
16 March 2019	13:22	85° 29 20	85°	0
17 March 2019	13:22	85° 52 32	86°	+1
18 March 2019	13:22	86° 15 31	86°	0
19 March 2019	13:21	86° 40 20	87°	+1
20 March 2019	13:20	87° 04 49	87°	0
21 March 2019	13:20	87° 28 06	85°	-2

22 March 2019	13:20	87° 51 03	86°	-1
23 March 2019	13:20	88° 13 27	87°	-1
24 March 2019	13:19	88° 38 38	89°	+1
25 March 2019	13:19	89° 00 34	90°	+1
26 March 2019	13:19	89° 20 00	90°	+1
27 March 2019	13:18	89° 44 38	90°	+1
28 March 2019	13:18	89° 38 34	91°	+2
29 March 2019	13:18	89° 17 23	91°	+2
30 March 2019	13:17	88° 58 42	90°	+2
31 March 2019	13:17	88° 35 02	90°	+2

Referring to the table above, the observation results obtained by astrolabe show difference in values of the degree. The data produced shows a difference in value of either not less than two minutes or not more than two minutes as compared to the JUPEM's data. The difference can still be reliable and does not significantly affect the process of astronomical calculation. In addition to that, the difference in value was also affected by instrumental errors and human senses errors. Both errors are two of the most common errors affecting observation activities, especially involving traditional astronomical instruments which require careful observation. However, the results indicate that the use of astrolabe can be applied on observation activities to obtain data of a celestial object and is still proven to be relevant today.

Conclusion

Astrolabe was created and has been used thousands of years ago for observation and calculations related to celestial objects. Instruments created with limited facilities during olden times are a noteworthy success. The creation and use of astrolabe are also important as this instrument used to manage the Muslims affairs such as the determination of Qibla direction and prayer time's calculation before the existence of such high-tech software as it is today. Based on the differences in the degree of the sun's altitude during transit using astrolabe, it shows that the accuracy of astrolabe is still proven to be relevant and suitable for today's use. The differences whisch are not less or exceed more than two degrees (2°) proved that astrolabe still can be used in this modern world for astronomical observation and calculation. Therefore, astrolabe should be developed and learned especially by the Muslim community to spread the knowledge and not be forgotten over time.

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