


Possibility of The Azimuth of Sirius Based on Stellarium for Determining the Qibla Direction

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Article Info	ABSTRACT
<p>Article History Received Revision Accepted</p> <hr/> <p>Keywords: Sirius Azimuth Qibla Direction Stellarium</p>	<p>Sirius is the brightest star in the night sky. We can calculate Sirius's azimuth to determine the difference in the azimuth of the Qibla. Therefore, people can use Sirius as a reference for determining the Qibla direction at night, providing an alternative when they cannot determine the Qibla direction during the day. This qualitative library research uses a descriptive form. The primary data is the calculation results of Qibla azimuth and its difference from Sirius azimuth. The secondary data includes astronomical data from Stellarium-web.org, Qibla formulation from the book <i>Ilmu Falak Arah Kiblat Setiap Saat</i> by Slamet Hambali, and interview data with astronomy enthusiasts.</p> <p>The Qibla direction determination using Sirius based on Stellarium data is fundamentally achieved by calculating the difference between Sirius's and Qibla's azimuth. The best time to apply this method is at night when the star is visible and free from cloud cover. In the Northern Hemisphere, Sirius is most clearly visible in January, February, March, October, November, and December. At the equator, it is visible year-round, except in January, June, and July. In the Southern Hemisphere, it is more reliable outside of May, June, and July. The ideal locations for Qibla direction measurement using Sirius are in the Southern Hemisphere and the Northern Hemisphere below 73° N latitude, with minimal light pollution and an unobstructed sky-view toward Sirius.</p> <div style="text-align: right; margin-top: 20px;">  </div>

I. Introduction

The Qibla is the direction towards the Kaaba (in Mecca) following the shortest path, which every Muslim must face during prayer [1, p. 20]. The Sun, as the closest star to the Earth and the general reference for astronomers in measuring the Qibla direction, can only be observed during the day under a clear sky. This limitation of using the Sun for Qibla direction determination presents a challenge. At night, when the Sun cannot be used as a reference for determining the Qibla direction, celestial objects such as the Moon, planets, stars, or constellations can be alternatives.

Celestial objects other than the Sun can be used to determine the Qibla direction provided they have an azimuth as a reference point, following the determination of its difference from the Qibla azimuth. [2, p. 2]. The Qibla azimuth is defined as the angle measured clockwise from the North point along the horizon circle to the projection of the Kaaba, Mekka [3, p. 83]. In geodetic astronomy, azimuth refers to the longitude in the horizontal coordinate system and the angle formed between a station's meridian plane and the vertical plane of a celestial object. Specifically, astronomical azimuth denotes the angle between the true north point and the vertical circle passing through a celestial object, measured along the horizon in a clockwise direction and ranging from 0° to 360° [4, p. 537].

Among the constellations observable, four are commonly used to find direction: the Crux, Orion, Ursa Major, and Scorpio [5, pp. 1-6], [6, p. 4]. There are also constellations with high-brightness stars, making them easily recognizable and observable to the naked eye. One of these stars is Sirius, located in the Canis Major. The Canis Major constellation, also known as the Great Dog, is southeast of the Orion constellation. The brightest star in this constellation is Sirius (Alpha Canis Majoris / α CMa), which is also the brightest star in the night sky [7, p. 94]. After the Sun, Sirius is the brightest star, with an apparent magnitude of -1.46 [8, p. Appendix-9].

In addition to being easily observable from Earth, Sirius's azimuth can also be calculated. Sirius azimuth can also be obtained through astronomy-based software, such as Stellarium, which is prominent among astronomy enthusiasts. Stellarium is software that functions like a virtual planetarium [9, p. 21]. It is a free, open-source program that can be used at no cost and can realistically display the sky in 3D, as it can be seen through the naked eye, binoculars, or a telescope [10, p. 222]. Stellarium is available on multiple devices, ranging from web-based platforms to Android and iOS applications [9, p. 21].

Once the position and azimuth of Sirius are determined, the star can serve as an alternative reference for finding the Qibla direction at night when daytime observations are obstructed by cloudy or rainy weather. Therefore, it is necessary to research the possibility of using Sirius as a reference for Qibla's direction. Possibility means "a chance that something may happen or be true" [11]. In this study, the possibility refers to the potential success of determining the Qibla direction using Sirius, with the star's azimuth obtained from Stellarium. This research aims to analyze the possibility of determining the Qibla direction using Sirius to achieve accurate Qibla direction results.

Literature Review

Studies related to determining the Qibla direction using stars with Stellarium as a source of astronomical data can be grouped into two categories. The first category involves studies

on determining the Qibla direction using stars or celestial objects. Imam Sarruji explains that determining the Qibla direction using the azimuth of stars and planets is a method based on the position of stars or planets as an alternative for determining Qibla direction at night [12]. Nurfahizya and Alimuddin explain that determining the Qibla direction using the azimuth of constellations or the azimuth of the Sun has the same level of accuracy [13]. M. Ali Romdhon explains that fishermen at Jepara, Indonesia use the Panjer star, Venus, as a reference for Qibla direction by facing the star and slightly turning to the right [14, p. 38].

Imam Fauzi explains that the direction of the Qibla can be determined by navigating using the Orion constellation as a reference [15, p. 87]. Besides that, Nizma Nur Rahmi explains that the manual calculation of the azimuth of the Acrux star, with data taken from the Nautical Almanac, can be used as a reference for determining the Qibla direction [2]. Celestial objects can be used as a reference if the azimuth value of the star is known, and the azimuth difference is calculated using the formula: $\text{azimuth difference} = \text{Qibla azimuth} - \text{star azimuth}$ [16].

Additionally, Samsul Halim explains that determining the Qibla direction at night with the help of the star Rigel has a high degree of accuracy. The difference in comparison to using the Sun is only in the minutes and seconds, specifically $0^{\circ} 1' 22.51''$, which is far below the Qibla direction deviation tolerance of 4° , as noted by Thomas Djamaluddin [17]. Samsul Halim's research is similar to Nizma Nur Rahmi's; both are relevant to this study, although the celestial objects and star azimuth were different.

The second category involves studies on astronomical data obtained from Stellarium. Moh. Choirull Chuluq explains that using Stellarium 3D software is relatively easy to understand because the application is automated. The law regarding the use of WinHisab software and Stellarium 3D software is similar to that of contemporary reckoning, as it relies heavily on detailed calculations [18]. Considering the accuracy of the astronomical data and the ease of access, this application is used in this research, particularly regarding the azimuth of Sirius and the simulation of Sirius's observation.

Based on the studies above, research on determining the Qibla direction using the Sun, planets, constellations, and stars is well-documented. However, based on the author's investigation, no study has examined the ideal conditions for using Sirius as a reference for determining the Qibla direction using Stellarium data. Therefore, this research explores the possibility of determining the Qibla direction using Sirius based on the star's azimuth from Stellarium.

II. Method

This research is qualitative research with a library research approach. The primary data consists of azimuth calculations for the Qibla and its difference with Sirius azimuth. The secondary data includes astronomical data of celestial objects from Stellarium-web.org, directional Qibla formula from the book *Ilmu Falak Arah Kiblat Setiap Saat* by Slamet Hambali, and star observation techniques from astronomy enthusiasts. Data collection techniques include documentation, experimentation, observation, and interviews.

The astronomy simulation software used to obtain the azimuth data for Sirius at specific times is Stellarium. Stellarium allows researchers to simulate the stars' positions in the sky at

various locations and times, enabling the data obtained to calculate the Sirius azimuth and its difference from the Qibla azimuth. Subsequently, a descriptive qualitative data analysis is conducted, detailing the methods, times, and locations for determining the Qibla direction using Sirius to achieve accurate results.

III. Results and Discussion

Method for Determining the Qibla Direction Using Sirius Based on Stellarium Data

It is essential to identify the position of Sirius in the night sky. Stellarium can help estimate the Sirius position by referencing the surrounding stars or constellations. Once the Sirius position is known, the observer can determine the Qibla direction by calculating the difference between the Sirius azimuth and Qibla azimuth [2, p. 74]. For example, if the azimuth of Sirius is $105^{\circ}25'30''$, and the Qibla azimuth is $290^{\circ}18'45''$, we can calculate the azimuth difference using the formula: $\text{azimuth difference} = \text{Qibla azimuth} - \text{star azimuth} = 290^{\circ}18'45'' - 105^{\circ}25'30'' = 184^{\circ}53'15''$.

Qibla direction can be determined using a theodolite, similar to how the Qibla direction is determined based on the Sun's position at any given time. The theodolite measures horizontal and vertical positions with arc-second precision [19, p. 263]. When determining the Qibla direction using stars, observers use the theodolite to measure the horizontal angle for the azimuth difference, which indicates the Qibla direction.

The data needed in this research to determine the Qibla direction at night using Sirius includes the following:

1. Azimuth of Sirius: obtained from Stellarium software.
2. Measurement time: obtained from *jam.bmkg.go.id* website.
3. Latitude and longitude of the location: obtained from the GPS (Global Positioning System) Garmin 60 devices.
4. Latitude and longitude of the Kaaba: refer to the Kaaba's latitude and longitude as cited in Slamet Hambali's book, based on Google Earth 2010, which are $39^{\circ}49'34.33''$ E and $21^{\circ}25'21.04''$ N [3, p. 14].

Steps for determining the Qibla direction using Sirius with Stellarium and the theodolite are as follows:

1. Prepare the theodolite by setting it up on a tripod, ensuring it is level with the Earth's surface. Place the theodolite on the tripod and ensure it is vertically aligned by adjusting the theodolite's water level. Don't forget to install the battery on the side of the theodolite. Once ready, turn on the theodolite and ensure it is unlocked.
2. Observe and aim at Sirius using the theodolite's lens, lock the theodolite in place, and press the reset button.
3. Record the time when the star is observed.
4. Record the azimuth of Sirius obtained from Stellarium, ensuring the coordinates and time in Stellarium match the observation location and time.
5. Calculate the Qibla azimuth using the following required data: latitude of the location (Φ^x), longitude of the location (λ^x), latitude of the Kaaba (Φ^k), longitude of the Kaaba (λ^k), and longitude difference (C, which is the difference between the longitude of the Kaaba and the longitude of the observation location).

To find the value of C (longitude difference) [1, p. 40], the following rules apply:

- 1) If the longitude of the location (λ^x) E $>$ the longitude of the Kaaba (λ^k), then $C = \lambda^x - \lambda^k$ (Qibla direction West).
- 2) If the longitude of the location (λ^x) E $<$ longitude of the Kaaba (λ^k), then $C = \lambda^k - \lambda^x$ (Qibla direction East).
- 3) If the longitude of the location (λ^x) W $<$ 140°10'20" W, then $C = \lambda^x + \lambda^k$ (Qibla direction East).
- 4) If the longitude of the location (λ^x) W $>$ 140°10'20" W, then $C = 360 - \lambda^x - \lambda^k$ (Qibla direction West).

Calculate the Qibla direction (B) [3, p. 39], using the following formula:

$$\text{Cotan } B = \tan \Phi^k \times \cos \Phi^x \div \sin C - \sin \Phi^x \div \tan C \quad (1)$$

If B is positive (+), the Qibla direction is measured from the North. If negative (-), it is measured from the South. Then the Qibla azimuth is determined [3, pp. 22–23], as follows:

- 1) If B = NE (+), then Qibla azimuth = B (unchanged).
 - 2) If B = NW (+), then Qibla azimuth = 360° - B.
 - 3) If B = SE (-), then Qibla azimuth = 180° - B, with B being positive.
 - 4) If B = SW (-), then Qibla azimuth = 180° + B, with B being positive.
6. Calculate the azimuth difference between Sirius and the Qibla [2, p. 74], using the formula:

$$\text{Azimuth Difference} = \text{Qibla Azimuth} - \text{Sirius Azimuth} \quad (2)$$

7. Unlock the theodolite, then rotate it until the Horizontal Angle (HA) displays the azimuth difference value. If the azimuth difference is positive (+), rotate the theodolite clockwise. If negative (-), rotate counterclockwise. Once the theodolite is correctly aligned with the azimuth difference, lock it in place to face the Qibla direction.
8. Finally, sight two points ahead of the theodolite using its lens and mark these two points. Connecting these two points with a line will indicate the Qibla direction.

Analysis of the Ideal Observation Time for Determining the Qibla Direction Using Sirius

Determining the Qibla direction using Sirius requires observing the star. Therefore, the first consideration for the ideal time of Qibla direction measurement using Sirius is identifying when the star is observable in the sky.

a. Sirius can be observed at night.

Sirius has an apparent magnitude of -1.46, while the Sun has an apparent magnitude of -26.72 [8, p. Appendix-9]. This means the Sun is 18.30137 times brighter than Sirius, so Sirius's light will be overshadowed if it is in the sky with the Sun. Thus, Sirius can only be observed at night. However, Sirius is not visible every night; the observer's latitude affects whether Sirius can be seen in the night sky.

Additionally, during nights around the full moon (for a week or more after the full moon phase), the Moon's brightness creates significant skyglow [20]. This effect is

similar to light pollution from artificial lights, making fainter stars or celestial objects more difficult to observe. Therefore, the best time to observe stars at night, considering the Moon's brightness, is about two weeks before the new moon phase, when the Moon is not in the night sky, or it sets a few hours after sunset, or it doesn't rise until dawn [21]. However, bright planets and stars like Sirius can still be seen even during the full moon phase or when approaching it, provided that there is no excessive light pollution obscuring the star [20].

b. When Sirius can be observed in the night sky in the Northern Hemisphere

Sirius has a declination of nearly -17° , so according to the rule that a star is visible above the horizon if $\delta > \Phi - 90^\circ$ (the star's declination is greater than the latitude of the location minus 90°), Sirius can be observed from anywhere on Earth, including locations in the Northern Hemisphere with latitudes below 73° N [22, p. 202]. The greater the latitude of a region, the more significant the difference in day and night duration due to the Earth's axial tilt of about 23.5° [23, p. 4].

A sample observation simulation via Stellarium was conducted in Berlin, Germany, with coordinates 52.51704° N and 13.38886° E, standard time +1 GMT in 2022. The data obtained is as follows:

Table 1. Visibility of Sirius in the Night Sky over Berlin, Germany, in 2022.

Bulan	Jam (GMT +1)																	
	21:00	22:00	23:00	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00
Januari		Sun set	X	Sirius rise	O	O	O	O	O	O	O	O	Sirius set	X	X	X	X	Sun rise
Februari		Sirius rise	Sun set	O	O	O	O	O	O	O	Sirius set	X	X	X	X	X	Sun rise	
Maret				Sun set	O	O	O	O	Sirius set	X	X	X	X	X	X	Sun rise		
April					Sun set	O	Sirius set	X	X	X	X	X	X	X	Sun rise			
Mei					Sun + Sirius set	X	X	X	X	X	X	X	X	Sun rise				
Juni			Sirius set			Sun set	X	X	X	X	X	X	Sun rise					Sirius rise
Juli	Sirius set					Sun set	X	X	X	X	X	X	X	Sun rise		Sirius rise		
Agustus					Sun set	X	X	X	X	X	X	X	X	Sun + Sirius rise				
September				Sun set	X	X	X	X	X	X	X	Sirius rise	O	O	Sun rise			
Oktober			Sun set	X	X	X	X	X	X	Sirius rise	O	O	O	O	O	Sun rise		
November		Sun set	X	X	X	X	X	Sirius rise	O	O	O	O	O	O	O	O	Sun rise + Sirius set	
Desember	Sun set	X	X	X	X	Sirius rise	O	O	O	O	O	O	O	O	Sirius set	X	X	Sun rise

From the table above (O indicates Sirius is visible, X means it is not), it is evident that in the Northern Hemisphere (particularly locations below 73° N latitude), Sirius can be observed in the night sky in January, February, March, April, September, October, November, and December. However, in the middle of the year (May, June, July, and August), Sirius is not visible in the night sky. During that month or mid-year, Sirius sets a few hours before sunset and only rises a few hours after sunrise, making it impossible to observe Sirius above the horizon at night.

Considering the duration Sirius remains above the horizon during the night according to Table 1, the longest duration occurs during the winter months of

November, December, January, and February. However, the sky tends to be cloudier during the winter. The following table shows the percentage of cloud cover in Berlin:

Table 2. Percentage of Cloud Cover in Berlin, Germany, Throughout the Year [24].

	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Okt	Nov	Des
langit berawan	69%	65%	61%	54%	49%	47%	45%	46%	49%	59%	71%	73%
cerah	31%	35%	39%	46%	51%	53%	55%	54%	51%	41%	29%	27%

One factor that influences celestial observations is the weather, particularly cloud cover. Table 2 lists the highest percentage of cloud cover in December, indicating that if Sirius is observed in Berlin during this month, its visibility might be obstructed by clouds. The skies begin to clear in April, during which Sirius can be seen as it sets following the Sun in the western sky, allowing for approximately 2 hours of observation. Although this is a relatively short period, it is still sufficient for observing Sirius. However, as Sirius sets, it is likely to be near the horizon, so observers must be in a location with an unobstructed view of the horizon to observe Sirius more easily.

Visible in the night sky over Berlin in March and October, Sirius stays above the horizon for five to six hours at night. Additionally, the percentage of cloud cover in March and October is not too high, at 61% and 59%, respectively. Therefore, the ideal times to observe Sirius in the Northern Hemisphere, specifically in Berlin, Germany, are in March and October.

c. When Sirius Can Be Observed in the Equatorial Region

The equatorial region of the Earth, or areas near the equator (at latitudes between 0° and 23° N or -23° S), experiences nearly equal day and night durations of approximately 12 hours. The researcher selected Pontianak, Indonesia, located at coordinates -0.02269° S and 109.34475° E with a +7 GMT zone as of 2022, to analyze the sunrise and sunset times as well as the rise and set times of Sirius, resulting in the following table:

Table 3. Visibility of Sirius in the Night Sky over Pontianak, Indonesia, in 2022

Bulan	Jam (GMT +7) WIB												
	17:00	18:00	19:00	20:00	21:00	22:00	23:00	00:00	01:00	02:00	03:00	04:00	05:00
Januari	Sun set	O	O	O	O	O	O	O	O	O	O	Sirius set	Sun rise
Februari		Sun set	O	O	O	O	O	O	O	Sirius set	X	X	Sun rise
Maret	Sun set	O	O	O	O	O	O	Sirius set	X	X	X	X	Sun rise
April	Sun set	O	O	O	O	Sirius set	X	X	X	X	X	X	Sun rise
Mei	Sun set	O	O	Sirius set	X	X	X	X	X	X	X	X	Sun rise
Juni	Sun set	Sirius set	X	X	X	X	X	X	X	X	X	X	Sun rise
Juli	Sun set	X	X	X	X	X	X	X	X	X	X	Sirius rise	Sun rise
Agustus	Sun set	X	X	X	X	X	X	X	X	Sirius rise	O	O	Sun rise
September	Sun set	X	X	X	X	X	X	Sirius rise	O	O	O	O	Sun rise
Oktober	Sun set	X	X	X	X	Sirius rise	O	O	O	O	O	O	Sun rise
November	Sun set	X	X	Sirius rise	O	O	O	O	O	O	O	O	Sun rise
Desember	Sun set	Sirius rise	O	O	O	O	O	O	O	O	O	O	Sun rise

According to the table (O indicates Sirius is visible, X means it is not), Sirius can be observed in the equatorial night sky throughout the year. However, during June and July, visibility is limited to its rising and setting times, resulting in brief observation windows.

In early June, Sirius sets in the western sky a few hours after sunset. A virtual observation via Stellarium shows that on June 1, 2022, in Pontianak, the sunset at 17:45 WIB, and Sirius followed at 19:56 WIB, allowing for 2 hours and 11 minutes of visibility. By late July, Sirius rises in the eastern sky just before sunrise. On July 31, 2022, in Pontianak, Sirius rose at 03:49 WIB, while the Sun followed at 05:46 WIB, providing 1 hour and 57 minutes of visibility before sunrise.

Sirius remains visible throughout the night in January and December. However, January in Pontianak is the cloudiest month, with overcast or mostly cloudy skies 89% of the time [25]. The high cloud cover significantly reduces the chances of observing Sirius, as clouds obscure its visibility. For optimal observation in the equatorial region, Sirius is best viewed at night throughout the year, except in January due to persistent cloud cover, in June when it sets near sunset, and in July when it rises close to sunrise.

d. When Sirius Can Be Observed in the Southern Hemisphere

Sirius has a declination of nearly -17° , meaning it can be seen throughout the Southern Hemisphere. Additionally, if $\delta > +90^\circ - \Phi$ (for the Northern Hemisphere) and $\delta < -90^\circ - \Phi$ (for the Southern Hemisphere), the star is circumpolar, meaning it always remains above the horizon and never sets [26, p. 19]. Sirius can even be observed as a circumpolar star in some regions of the Southern Hemisphere.

When Sirius is circumpolar, it can be observed all night and all year because it will always be above the horizon. Sirius appears circumpolar when observed from latitudes south of 73° , such as at coordinates $77^\circ 50' 47''$ S in McMurdo Station, Ross Island, Antarctica. Based on the star movement simulation conducted using the

Stellarium application, Sirius appears to rotate above the horizon throughout the year in the sky over McMurdo Station, with a minimum altitude of 4°.

In the Southern Hemisphere regions where Sirius is not circumpolar, at latitudes below 73° S, Sirius can be observed at night throughout the year, though the duration varies each month. Areas in the Southern Hemisphere have differences in day and night duration due to the Earth's axial tilt. This difference in duration also affects how long Sirius can be seen in the night sky.

A sample observation simulation via Stellarium was conducted in Ushuaia, Argentina, at coordinates -54.80612° S and 68.31850° W, with a -3 GMT zone in 2022. The data obtained is as follows:

Table 4. Visibility of Sirius in the Night Sky over Ushuaia, Argentina, in 2022.

Bulan	Jan GMT -3																		
	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00		
Jan						Sun set	O	O	O	O	O	O	Sun rise			Sirius set			
Feb					Sun set	O	O	O	O	O	O	O	O	Sun rise/ Sirius set					
Mar				Sun set	O	O	O	O	O	O	O	Sirius Set	X	X	Sun rise				
Apr		Sun set	O	O	O	O	O	O	O	Sirius Set	X	X	X	X	X	Sun rise			
Mei	Sun set	O	O	O	O	O	O	Sirius Set	X	X	X	X	X	X	X	X	Sun Sirius rise		
Jun	Sun set	O	O	O	O	Sirius Set	X	X	X	X	X	X	X	X	Sirius rise	O	Sun rise		
Jul	Sun set	O	O	Sirius Set	X	X	X	X	X	X	X	X	Sirius rise	O	O	O	Sun rise		
Agust		Sun Sirius set	X	X	X	X	X	X	X	X	Sirius rise	O	O	O	O	Sun rise			
Sept			Sun set	X	X	X	X	X	Sirius rise	O	O	O	O	O	Sun rise				
Okt				Sun set	X	X	Sirius rise	O	O	O	O	O	O	Sun rise					
Nov				Sirius rise	Sun set	O	O	O	O	O	O	O	Sun rise						
Des			Sirius rise			Sun set	O	O	O	O	O	Sun rise							

Sirius can be observed in the night sky in this region throughout the year. The star remains above the horizon for approximately 5-10 hours at night in Ushuaia, providing ample time to observe Sirius. According to Table 4, Sirius can be observed throughout the night in January, February, November, and December, with the longest duration above the horizon being approximately 10 hours in February.

Sirius cannot be observed at midnight in May, June, July, and August because, during these months, Sirius sets before midnight and rises shortly before sunrise. Additionally, May and June are the cloudiest months of the year in Ushuaia, with the sky being overcast or mostly cloudy 64% of the time [27]. Therefore, it is better to observe Sirius outside of these months, as the chances of seeing the star without cloud cover are higher, and the duration of the star above the horizon is longer.

Analysis of the Ideal Locations for Determining the Qibla Direction Using Sirius

Several considerations need to be made while deciding where to observe Sirius. Besides being in a region where Sirius is visible above the horizon (i.e., all latitudes in the Southern Hemisphere and Northern Hemisphere below 73° N latitude), the ideal characteristics for observing and sighting Sirius include the following:

a. **Minimal Light Pollution**

The effect of outdoor lighting, including street and highway illumination, is light pollution. Light pollution is defined as excessive artificial light that is unwanted, primarily caused by inefficient and misdirected lighting systems, [29, p. 190]. One of the consequences of light pollution is sky glow, which can reduce the darkness of the night sky and interfere with the observation of celestial objects [28, p. 292]. The sky gets brighter as light pollution increases, making it harder to see dim celestial objects. Consequently, observations of stars or celestial objects are most effectively performed in areas with reduced light pollution.

The Bortle Scale is one simple way to assess the luminosity of the night sky due to light pollution. This scale ranges from level 1 (excellent dark sky), representing the darkest skies on Earth, to level 9 (inner-city sky), representing urban skies with high light pollution, where only the brightest stars and planets are visible [30]. The higher the Bortle scale level, the brighter the sky due to increased light pollution.

Sirius, the brightest star in the night sky, can still be observed even in urban areas. This was demonstrated through an observation of Sirius in Semarang City, Indonesia, on August 1, 2022, at 04:48 WIB. Below is an image of the night sky captured during the Sirius observation in that area, using a smartphone camera without editing, closely resembling what the human eye perceives.



Figure 1. Documentation of the Night Sky in Semarang City using a Samsung A52 smartphone camera.

As shown in Figure 1, Sirius can still be observed in urban areas categorized within the Bortle scale 8-9, although the star appears dim. According to Avivah Yamani, an astronomy enthusiast from Bandung Technology Institute, urban light pollution is generally high, especially during the full moon, which creates an effect similar to light

pollution, making only the brightest stars and planets visible [20]. While Sirius is one of the stars that can be seen even under high light pollution conditions, the ideal location for observing and sighting Sirius would naturally be in an area with minimal light pollution, as less light pollution allows stars to appear brighter and clearer.

b. Landscape or Wide Field of View

Another crucial factor when selecting an ideal location for observing Sirius is the landscape or the observer's field of view. The observation site should have an unobstructed view of the surroundings or at least a clear view of the direction of the celestial object to be observed. For instance, in August, at the equator, Sirius is located in the southeastern sky, so it is important to ensure that no trees, buildings, or other objects obstruct the observer's view of that part of the sky.

The ideal location for determining the Qibla direction using Sirius is in areas where Sirius is visible above the horizon, which includes all regions in the Southern Hemisphere and Northern Hemisphere below 73° N latitude. Additionally, this location should have minimal light pollution and a wide, unobstructed view toward Sirius.

Advantages and Disadvantages of Determining the Qibla Direction Using Azimuth of Sirius

Determining the Qibla direction using Sirius offers several advantages. One significant benefit is a practical alternative for nighttime Qibla determination. Additionally, this approach is valuable when determining the Qibla direction for outdoor prayer spaces, such as during Eid, especially when measurements need to be taken at night. The accuracy of this method is noteworthy because the theodolite, used in the process, targets a single central point of Sirius, unlike the Sun, where the targeting relies on reflected light. This precise targeting contributes to the overall accuracy of the Qibla direction measurement.

However, there are some limitations to using Sirius for Qibla determination based on Stellarium data. One drawback is that Sirius is not visible every night; there are certain times when the star does not appear above the horizon. Consequently, observers must be aware when Sirius is visible to apply this method effectively. Another significant limitation is that individuals north of 73° N latitude cannot see Sirius above the horizon, rendering it impossible to determine the Qibla direction using this star. Additionally, the equipment necessary for this method, such as a theodolite, is relatively costly. This financial barrier may restrict access to the required tools, potentially hindering the broader adoption of this method.

IV. Conclusion

Sirius can be used as a reference for determining the Qibla direction, with its azimuth data obtainable from Stellarium software. Determining the Qibla direction using Sirius based on Stellarium data primarily involves calculating the azimuth difference, which is the azimuth of the star minus the azimuth of the Qibla. Therefore, a tool capable of sighting Sirius and measuring the horizontal angle as a projection of the azimuth difference is required, with the theodolite being the most commonly used instrument.

The best time to measure the Qibla direction using Sirius is at night when the star is visible and free from cloud cover. In the Northern Hemisphere, Sirius is most clearly visible

in January, February, March, October, November, and December. At the equator, it is visible year-round, except in January, June, and July. In the Southern Hemisphere, Sirius observation is more reliable outside of May, June, and July. The ideal locations for Qibla direction measurement using Sirius are in the Southern Hemisphere and the Northern Hemisphere below 73° N latitude, with minimal light pollution and an unobstructed sky-view toward Sirius.

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