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OBSERVATION OF DAWN SPECTRAL SHIFTS: TRANSITION FROM *FAJAR KAẐIB* TO *FAJAR ṢADIQ* IN DETERMINING THE BEGINNING OF FAJR PRAYER TIME AT THE UIN WALISONGO OBSERVATORY SEMARANG

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Abstract: *This research analyzes the color change from false dawn (fajar kaẑib) to true dawn (fajar ṣadiq) in determining the beginning of the Fajr prayer time at the UIN Walisongo Observatory in Semarang. A camera, adjusted to match visual perception, was used to record RGB intensity at regular intervals. Results indicate a significant increase in the red spectrum as true dawn appears, distinct from false dawn. Comparative analysis of RGB ratios, moving averages, and linear fitting identified a pattern of change and an inflection point at a solar altitude of -19.81° or 04:00 WIB, which reliably detects the transition between the two dawns. This method offers a more precise alternative for determining the Fajr prayer time*

Keywords: *Fajr, RGB Intensity, Islamic Astronomy*

Introduction

The beginning of Fajr prayer time is a critical determination in the daily worship practices of a Muslim, as it marks the start of the day's religious obligations. Fajr time is marked by true dawn (*fajar ṣ adiq*), also known in astronomy as astronomical twilight, which is the phenomenon of genuine light appearing below the horizon, generated by sunlight illuminating the Earth's atmosphere (Wahidin, 2023). This differs from false dawn (*fajar kaẑ ib*), or zodiacal twilight, a false dawn resulting from sunlight reflected by interplanetary dust shortly before true dawn in the eastern sky (Ardhi, 2020). The distinction between false dawn and true dawn often leads to controversy over the start of Fajr, as both are gradual and visually subjective, presenting as color reflections due to changes in intensity and photon scattering.

While classical Islamic tradition has maintained a clear understanding of the distinction between false dawn (*fajar kaẑ ib*) and true dawn (*fajar ṣ adiq*), as described in the Qur'an and the Hadith of Prophet Muhammad SAW, the practice of determining Fajr time in the modern era often relies on astronomical calculations based on the sun's position below the horizon, typically without direct visual observation (Azhari, 2017). An important question arises regarding how well the Fajr times listed in Islamic calendars—which are usually based on a specific solar angle below the horizon—align with the actual appearance of true dawn in the sky (Utari, 2018). Previous studies have indicated that atmospheric factors and geographical variations can influence the timing of true dawn's appearance (Sado, 2015). Therefore, direct observations at specific locations, such as those conducted at the UIN Walisongo Observatory in Semarang, are crucial for obtaining more accurate and context-specific empirical data in determining the beginning of Fajr prayer time.

Current observational models generally utilize a Sky Quality Meter (SQM) to measure changes in sky light intensity from false dawn (*fajar kaẑ ib*) to the appearance of true dawn (*fajar ṣ adiq*), with a primary approach being to identify the inflection point on the sky brightness (magnitude) graph. In this method, changes in light intensity detected by the SQM or through photographic techniques are continuously monitored. The primary light source in these observations shows an increasing intensity over time, appearing progressively brighter as true dawn approaches. This method assumes that zodiacal light, or false dawn, has a relatively constant intensity, which can be identified and separated from other light sources. Consequently, the appearance of true dawn can be estimated using a linear function approach applied to light intensity data, which is assumed to be linear over the observation period (Setyanto, 2021).

This research holds significance in achieving more precise determination of Fajr prayer timing through direct visual observation of dawn phenomena. The conventional approach, which utilizes the sun's position below the horizon, does not always take into account factors such as atmospheric variations and geographical conditions that may affect the appearance of true dawn (*fajar ṣ adiq*). In contrast, most prior studies have relied on the Sky Quality Meter (SQM), which can only measure overall sky light intensity without distinguishing changes in color. However, color change is considered more reliable in detecting the transition from false dawn (*fajar kaẑ ib*) to true dawn, making the RGB (Red, Green, Blue) approach promising for providing more detailed and accurate results.

The RGB approach in this study enables more specific observation of color distribution during the transitional phase between false dawn (*fajar kaẑ ib*) and true dawn (*fajar ṣ adiq*), particularly by identifying changes in the red (R), green (G), and blue (B) spectra. This technique provides an opportunity to capture the dominant color spectrum that appears at true dawn, aiding in a more precise marking of Fajr prayer time. With spectral data from each color, this study will record more detailed differences in light intensity distribution, measuring not only overall brightness but also the color components, which serve as stronger indicators for the onset of true dawn.

Based on this observational model, the hypothesis in this study posits that the red component in the RGB spectrum will show a significant increase at true dawn (*fajar ṣ adiq*) compared to false dawn (*fajar kaẑ ib*), following a linear pattern identifiable in the spectral intensity graph. This hypothesis will be tested using a moving average and linear fitting approach on the observational data to more clearly detect the transition to true dawn. Thus, the RGB approach is expected to yield more accurate empirical observations, which can later serve as a recommendation for determining Fajr prayer time based on visual conditions consistent with the appearance of true dawn.

This study, therefore, seeks to directly observe the color changes in the sky during the transition from false dawn (*fajar kaẑ ib*) to true dawn (*fajar ṣ adiq*) and to identify the visual and spectral characteristics that serve as indicators for the beginning of Fajr prayer time. This direct observation is supported by a camera instrument calibrated to match human visual perception, used to capture color changes and light intensity objectively and measurably. Additionally, this research aims to provide a more reliable Fajr time recommendation based on local conditions in Semarang, which may not always align with other regions, thus serving as a reference in developing a prayer time calendar. This approach is anticipated to enhance the accuracy of Fajr prayer time determination, aligning it more closely with Islamic principles.

Literature Review

Research by Hendro Setyanto and Muhammad Basthoni highlights the importance of light pollution factors in dawn observation, particularly in determining the Fajr prayer time. In his journal article titled "*Zodiac Light Detection Based on Sky Quality Meter (SQM) Data: Preliminary Study*", Setyanto demonstrates that zodiacal light, or false dawn (*fajar kaẑ ib*), can be detected in light-polluted locations, showing a linearly decreasing light intensity pattern at a solar altitude below -20°, although this light is not as distinct as true dawn (*fajar ṣ adiq*) (Setyanto, 2021). Meanwhile, Basthoni, in his dissertation titled "*The Effect of Light Pollution on Determining the Start of Fajr Time in Indonesia*" found that light pollution significantly affects the initial detection of true dawn, impacting its visibility by up to 77%. In locations with ideal night sky conditions (≥ 21.3 mpsas), true dawn is detected at a solar depression angle of approximately -19.73 ± 0.19 degrees, but in brighter locations, the detection of true dawn is delayed. Both studies underscore the importance of considering light pollution in Fajr time observations and the need for light pollution correction to improve observation accuracy, particularly under high-pollution sky conditions (Basthoni, 2022).

Method

This study was conducted by collecting observational data on the dawn phenomenon at the UIN Walisongo Semarang Observatory, located at coordinates 110˚ 20′ 53″ E, 06˚ 59′ 29″ S. The site is classified under Bortle class 6 Sub-Urban Sky, with sky magnitude ranging from 18.94 to 19.50 MPSAS and 5.0 to 5.5 NELM (Huda, 2023). Key parameters in data collection included the use of a camera to capture the sky's color changes (RGB), camera position adjustments relative to the horizon, and additional parameters such as the sun's altitude (*ho*) below the horizon. Data were collected at specific times during the transition phase from false dawn (*fajar kaẑ ib*) to true dawn (*fajar ṣ adiq*), and the observation site was carefully selected to minimize light pollution.

Data collection was conducted using a Xiaomi Redmi 13 smartphone camera (specifications: 108 megapixels, F/1.75, and pixel size of 1.92 µm) with a shutter speed set to 1/30 and ISO set to 6400, adjusted to match human visual perception for capturing RGB color distribution at the eastern horizon, where dawn appears. The camera was configured in time-lapse mode with a 1/60s interval, positioned steadily and directed toward the eastern horizon with orientation and angle adjusted to ensure that a 20° field of view (FOV) above the horizon was included in the frame, allowing for continuous recording of color changes throughout the transition from false dawn (*fajar kaẑ ib*) to true dawn (*fajar ṣ adiq*). Measurements were taken during the time period when both dawns appeared, while avoiding weather conditions, excessive pollution, and other atmospheric factors that could affect the observation results. The collected RGB data included the intensity of the red (R), green (G), and blue (B) components, which were then analyzed to determine the onset of true dawn (*fajar ṣ adiq*).

The collected data were analyzed using ImageJ and LabPlot software to create graphs of color intensity versus solar altitude (*ho*). The analysis was performed using "moving average" and "linear fitting" methods to identify linear changes in color intensity, particularly in the red (R) spectrum, which is expected to show a significant increase at true dawn (*fajar ṣ adiq*). This method allows for more objective and measurable mapping of light intensity changes by comparing the red (R) spectrum with other spectra (green and blue), thereby enabling a more accurate identification of the transition point from false dawn (*fajar kaẑ ib*) to true dawn (*fajar ṣ adiq*). The results of this analysis were then used to determine a more precise time for marking the beginning of Fajr prayer based on visual observations.

Results and Discussion

Time-lapse data collection was conducted using a camera on October 13, 2024, from 02:57 to 04:41 LT at the UIN Walisongo Observatory in Semarang, resulting in a total of 105 frames with varying solar altitudes (*ho*) ranging from -35.06° to -09.80°. A quantitative analysis of all frames was performed using ImageJ software to measure spectral intensity. Each frame was separated into three RGB channels: red (R), green (G), and blue (B). The region of interest (ROI) was focused on the eastern sky area, showing the transition from false dawn (*fajar kaẑ ib*) to true dawn (*fajar ṣ adiq*).

Figure 1. The area of true dawn (*fajar ṣ adiq*) appearance (ROI).

The intensity data from the region of interest (ROI) were then interpreted into graphical form using LabPlot software. The intensity comparisons for each channel were extracted by calculating the differences and plotting them. The first intensity curve represents the difference between the red (R) intensity and green (G) intensity, abbreviated as R-G, while the second curve represents the difference between the red (R) intensity and blue (B) intensity, abbreviated as R-B.

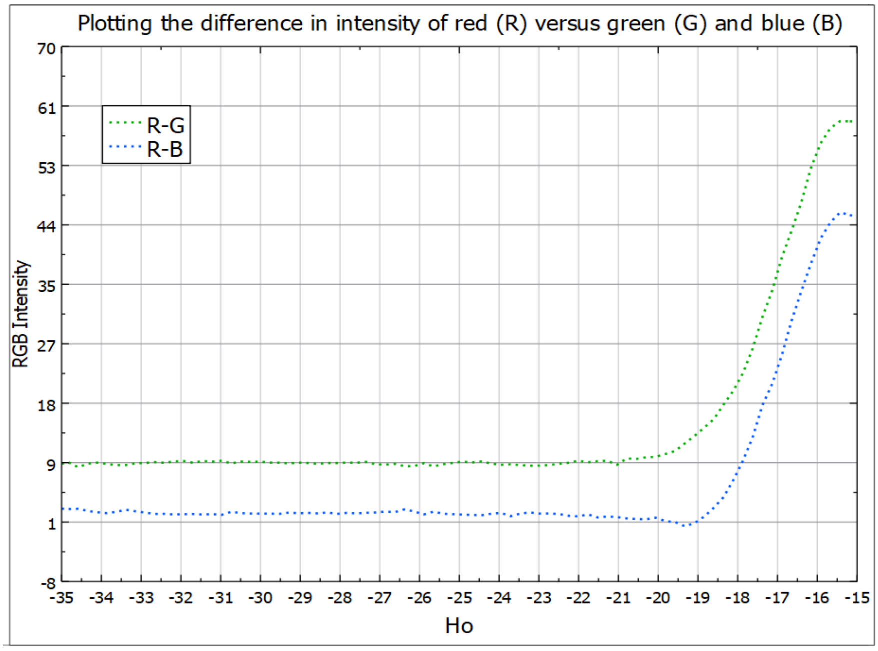
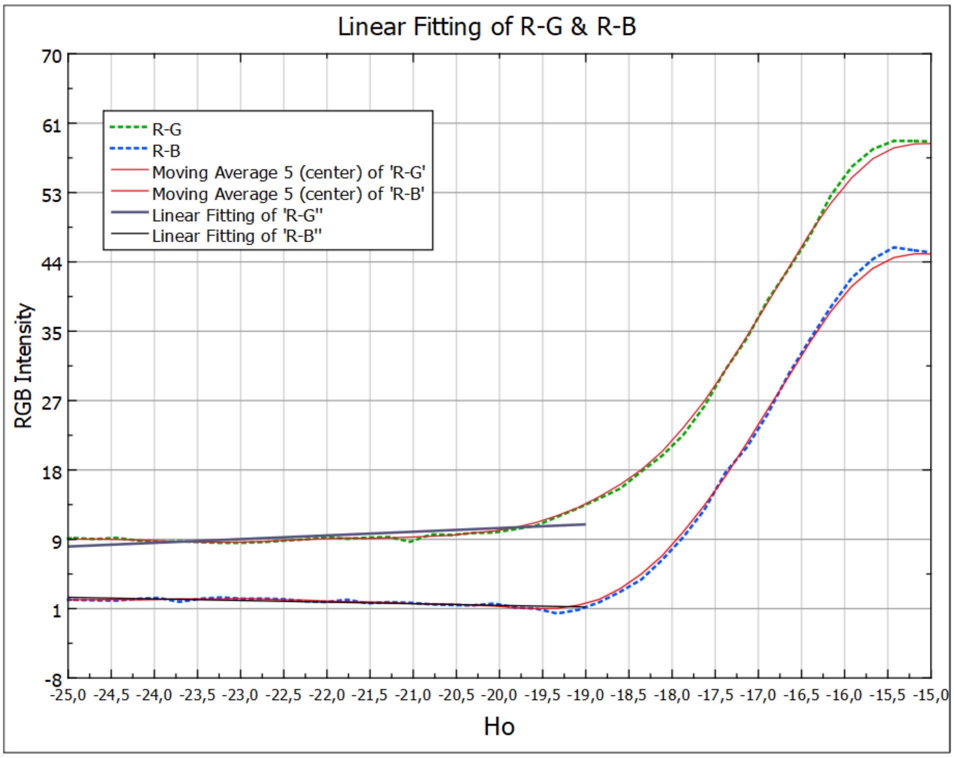


Figure 2. Difference curves between RGB channels.

A trend of increasing intensity difference in both R-G and R-B is observed as the solar altitude rises, particularly between the altitude range of -21° to -18°, where a significant inflection occurs. This indicates that the red (R) component becomes more dominant compared to the green and blue components as the sun ascends. This, in other words, marks the transition from false dawn (*fajar kaẑ ib*) to true dawn (*fajar ṣ adiq*). These changes in color intensity are strongly influenced by atmospheric conditions. In general, during sunrise or sunset, sunlight must pass through a thicker layer of the atmosphere compared to when the sun is directly overhead. The Rayleigh scattering process occurring in the atmosphere causes blue light to scatter more, while red light tends to pass through the atmosphere and reach the Earth's surface.

Specifically, in the context of dawn, the inflection in the trend can be further analyzed using "moving average" and "linear fitting" approaches. The moving average is applied to smooth the data and clarify the general trend. For this, every 5 data points are averaged, then stacked with the next 5 data points at the median of the previous 5 data points. This approach helps to reduce the influence of noise or random fluctuations in the data. Meanwhile, "linear fitting" is applied to highlight the overall trend in the relationship between the intensity difference and solar altitude (*ho*).



Gambar 3. Kurva diperhalus dan dicari titik belok.

After data processing, such as moving average calculation and linear fitting adjustment, several interesting observations can be made. The "moving average" line helps to clarify the general trend, while the linear line provides a rough indication of the linear relationship between the variables. The most notable feature is the presence of two inflection points, marked by the green and blue areas, as shown in Figure 4 below.

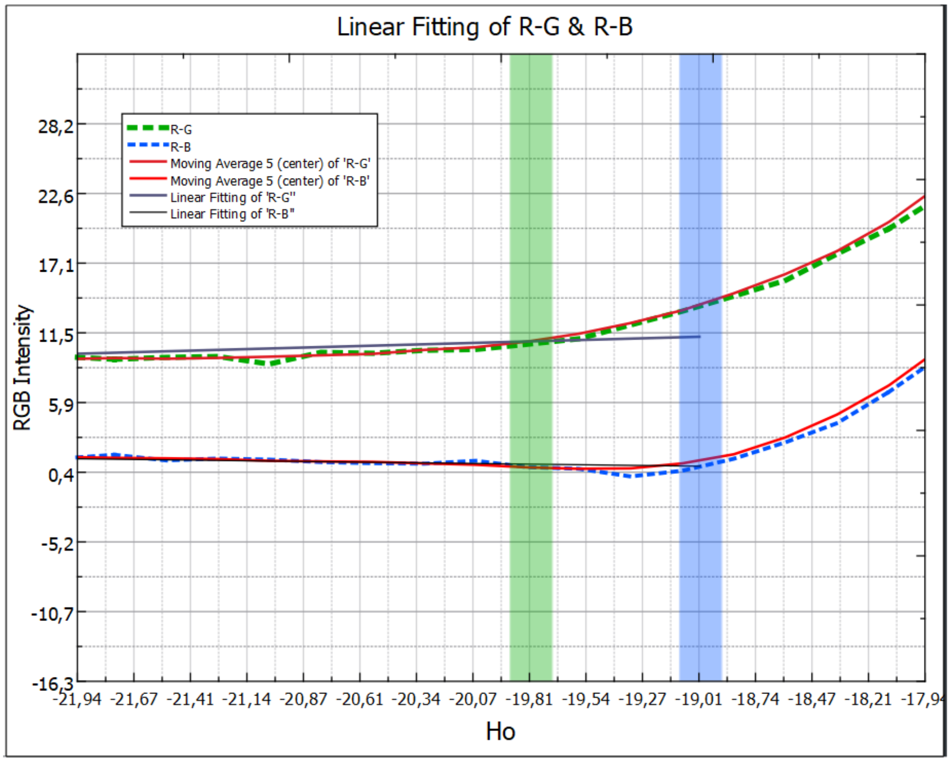


Figure 4. Shift points on the R-G and R-B curves.

These points indicate a sudden change in the rate of increase in intensity differences. The R-G curve shows a shift point at a solar altitude of -19.81°, while the R-B curve shifting at a solar altitude (*ho*) of -19.08°. The difference in solar altitude (*ho*) between these points suggests that the transition moment from false dawn (*fajar kaẑ ib*) to true dawn (*fajar ṣ adiq*) occurs within this altitude range.

Shift point intensity

Table 1. *Spectral shift at -19,81° until -19,01°*

Sun Altidude (°)	R-G	R-B	Local Time
-20,549	9,876	1,115	03:57
-20,305	10,115	1,075	03:58
-20,062	10,179	1,303	03:59
-19,818	10,595	0,798	04:00
-19,574	11,03	0,667	04:01
-19,331	12,133	0,058	04:02
-19,087	13,227	0,510	04:03
-18,843	14,43	1,466	04:04
-18,600	15,681	2,777	04:05
-18,356	17,798	4,305	04:06

Based on the table above and its relation to the onset of true dawn (*fajar ṣ adiq*), considering the gradual nature of the visual color characteristics, the R-G curve, or the green area, shows a greater proportion than the R-B curve, or the blue area. In other words, at a solar altitude (*ho*) of -

19.81°—which, when converted to local time, corresponds to 04:00 LT—true dawn (*fajar ṣ adiq*) has already occurred, marking the beginning of Fajr prayer time. Meanwhile, the R-B curve represents the continued increase in brightness of true dawn until sunrise.

The results above show that the observation and quantitative analysis of color intensity from dawn, using the RGB separation technique, provide data that supports the visual identification of true dawn (*fajar ṣ adiq*). With shift points found at solar altitudes (*ho*) of approximately -19.81° for the R-G curve and -19.08° for the R-B curve, we can conclude that the transition from false dawn (*fajar kaẑ ib*) to true dawn (*fajar ṣ adiq*) can be identified through the analysis of color intensity caused by atmospheric scattering. This aligns with the spectral characteristics of dawn, where red becomes more dominant as true dawn (*fajar ṣ adiq*) appears.

This trend also indicates that at a solar altitude (*ho*) of -19.81° (approximately 04:00 LT), the red color in the spectrum becomes more prominent compared to green and blue. This suggests that at this moment, the light intensity arriving from the eastern horizon exhibits distinctive characteristics of the appearance of true dawn (fajar ṣ adiq), which can be used as a reference for determining the start of Fajr prayer time.

The use of "moving average" helps to reduce data fluctuations and highlights a clearer overall intensity trend. This trend reveals the gradual transition from false dawn (*fajar kaẑ ib*) to true dawn (*fajar ṣ adiq*), and "linear fitting" emphasizes a linear relationship between solar altitude (*ho*) and the RGB intensity differences during this phase. Furthermore, the presence of two shift points on the curves indicates moments of sudden changes in light intensity in the sky, which are associated with the appearance of true dawn (*fajar ṣ adiq*) as the marker for the beginning of Fajr prayer time.

This analysis supports the importance of visual parameters in the identification of true dawn (*fajar ṣ adiq*), a crucial indicator in astronomy and the determination of prayer times. The spectral changes in light during dawn have significant implications for dawn observation methods, particularly in developing more accurate techniques based on optical observation. With this analytical approach, research in Islamic astronomy can enhance the precision of determining Fajr prayer times, which have traditionally relied on visual methods or theoretical calculations.

Conclusion

This study successfully identified the transition from false dawn (*fajar kaẑ ib*) to true dawn (*fajar ṣ adiq*) by analyzing the RGB spectral intensity of images of the eastern sky taken at the UIN Walisongo Semarang Observatory. The measurement results show that the difference in intensity between red and green (R-G) and red and blue (R-B) increases with the rising sun. A significant change in the intensity difference occurs within the altitude range of -21° to -18°, indicating the increasing dominance of red light, with turning points at -19.81° for the R-G curve and -19.08° for the R-B curve, signaling the emergence of *fajar ṣ adiq* as the start of Fajr prayer time. Based on this analysis, true dawn (*fajar ṣ adiq*) is estimated to appear at sun altitude (*ho*) of -19.81°, or around 04:00 LT. The "moving average" and "linear fitting" methods have proven effective in reducing fluctuations and clarifying spectral intensity, helping to identify true dawn (*fajar ṣ adiq*) more accurately. Therefore, this research contributes to the development of more scientific and precise methods for determining the start of Fajr prayer time in Islamic astronomy.

Acknowledgement

We would like to express our gratitude to the Head of the UIN Walisongo Semarang Observatory for their support of this research, including the provision of equipment and facilities used during data collection. This support enabled us to gather data on October 13, 2024, from 02:57 to 04:41 LT, resulting in a total of 105 frames. We also extend our heartfelt thanks to Allah SWT for granting ease and success throughout the research process. We hope that the findings of this study

will contribute to the advancement of Islamic astronomy and provide a meaningful contribution to the more accurate and scientific determination of the start of Fajr prayer time.

Conflict of Interest

The authors declare that there are no conflicts of interest related to this research. This study was conducted independently, without any influence or support from third parties that could affect the results and interpretation of the data. All analyses and conclusions presented are entirely based on the observational results and objective scientific methods.

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