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Color Space Transformation to Identify the Disappearance of *Syafaq* as the Beginning of Isha Prayer

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ABSTRACT

Early prayer times began to be widely discussed in the past few years, since several opinions said that the beginning of prayer isha' and shubuh need to be corrected. This study focused on image processing approach to analyze the disappearance of *syafaq* rays as an early sign of the start of the Isha' prayer. The imagery data were taken in Lombok and Masalembu then transformed into different color spaces. RGB data transform to YUV, YCbCr, and L*a*b* spaces. The main contribution is evaluating these models to establish an objective, sensor-based baseline. Conceptually, L*a*b* is superior because it isolates chromaticity from luminance*, allowing the a∗ channel to track the vanishing reddish hue without being obscured by total light fluctuations. From L*a*b* color spaces have sensitively identified the disappearance of *syafaq*. A uniform typology of graphs was obtained in 4 color spaces as a sign that the initial physical analysis of beginning isha' times. A uniform graphic typology was obtained, where the Isha' time is marked by a plateau (flattening curve), indicating the rays have completely vanished. Results of the start of prayer times with color space transformation to identify the start of isha times close to the agreement in Indonesia.

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1. INTRODUCTION

The beginning of prayer time which is obligatory worship for Muslims has been regulated in the Qur'an and Hadith [1], [2]. The fuqaha have agreed that the start of the Isha' time is when the mega red syafaq arrives until the Fajr prayer begins. In Astronomy, this event is known as the end of the astronomical twilight (astronomical twilight) [3].

Problems arise when the concept of prayer time is implemented in the astronomy parameter as the height of the sun. The results of observations for observing prayer times are sometimes different from one to another. The government through the Indonesian Ministry of Religion uses the sun's height of 18°.2, KH. Drs. Slamet Hambali uses the height of the sun. -17°.3 and Prof. Tono Saksono use the sun's height of -11.5°.4, and many others. One of the causes of this difference is that some researchers draw conclusions based on the results of their opinions so that the results of their research have a high level of subjectivity [4], [5].

The signs of the entry of Isha' time have been agreed based on Islamic law, namely when the loss of *syafaq*. However, regarding the meaning of syafaq, some scholars tend to have different opinions [6], [1]. The first opinion is that *syafaq (syafaq al ahmar)* has a red color, and the second opinion *syafaq* has a white color *syafaq al-abyadh*. While the third opinion *syafaq* has two different meanings, namely red and white.

Astronomical science is important especially for Muslims because it is related to the implementation of worship, including prayer, fasting and pilgrimage [1]. While traditional methods rely heavily on visual observation (naked eye) or purely mathematical models, these approaches often introduce high levels of human subjectivity and atmospheric variability. The aim of this study is to minimize research subjectivity in analyzing the beginning of prayer times by proposing a new methodological framework. This approach utilizes image processing and color space transformation to provide a more objective and quantifiable alternative to traditional visual observations. By leveraging astrophotography techniques [7], [8], this research proposes to transition from qualitative visual assessment to a quantitative, pixel-based analysis.

Color transformation is a preliminary method to determine the beginning of prayer, especially Isha prayer. Astrophotography imagery is used as original data, and color transformation as an image processing method. Some previous research used the sky quality meter instrument [9], [10] to identify changes in sky brightness. Now we propose an alternative method by using color transformation to avoid subjectivity from the researcher. The sky quality meter instrument is limited to measuring scalar light intensity and cannot distinguish specific chromatic shifts. In Islamic astronomy, the beginning of Isha' is defined by the total disappearance of the reddish twilight *(Syafaq Ahmar)* from the horizon [1], [11]. Therefore, a more precise detection method is required to isolate these specific color components.

We propose an alternative method using color space transformation to precisely detect this phenomenon. The novelty of this work lies in the methodological refinement of using color-vector decay as a device-agnostic indicator, moving beyond simple scalar luminance, which is prone to local light pollution interference**.** The analytical advantage of color transformation lies in its ability to isolate the reddish chromatic components, providing a more definitive indicator of when the redness has fully faded compared to total luminance measurements from an SQM. The scientific contribution of this work is the establishment of a robust, color-based feature extraction method that objectively identifies the end of the twilight phase.

2. METHOD

This research follows a structured four-stage methodological framework: data acquisition, pre-processing, color transformation analysis, and validation (Figure 1). The methodology of this study is designed to transition from qualitative visual evidence to a quantitative framework through four distinct stages.

2.1 Instrumentation and High-Frequency Data Acquisition

To ensure the robustness of this preliminary study, data were collected using two different mobile sensors across two distinct geographical locations and seasons. The first dataset was acquired in Lombok (December 2021) using a Huawei BAH3-W59 sensor, while the second was in Masalembu (June 2022) using an Infinix X670. The parameters are shown in Table 1.

The cameras were mounted on tripods facing the Western Horizon (azimuth). We employed a high-frequency temporal sampling technique, capturing images at 1-minute intervals from sunset until 15 minutes after the predicted Isha' time. As detailed in Table 1, ISO and exposure parameters were dynamically adjusted (up to ISO 6400) to maintain chromatic sensitivity in low-light conditions.

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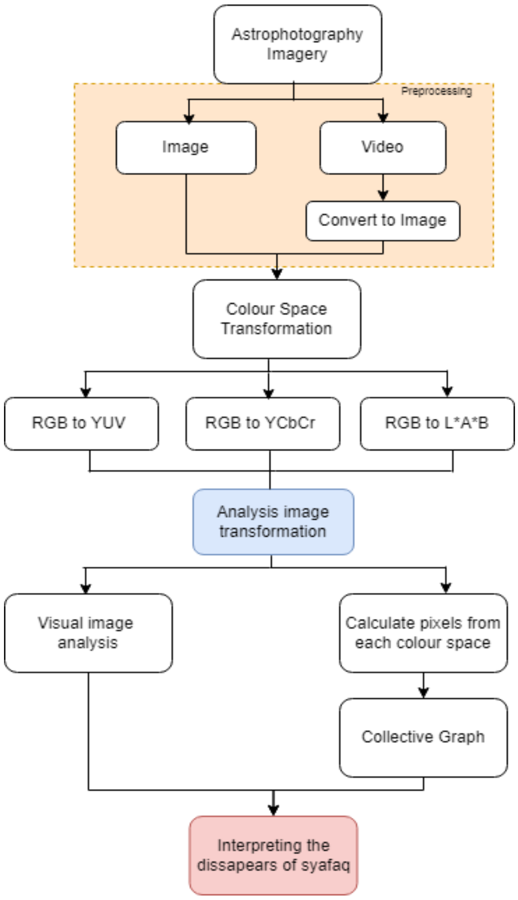

Figure 1. The methodology of analyzing syafaq by using color space transformation

Environmental conditions were strictly monitored, ensuring clear weather with minimal cloud obstruction. To ensure data integrity, the sky quality at both locations was assessed using the Bortle Scale, which quantifies the impact of light pollution on astronomical observations. The Masalembu site offered a Class 3.1 (Rural Sky) environment, while the Lombok site was characterized by a Class 3.8 (Rural) sky. The Bortle scale is a nine-level numeric scale where a Class 3 rating signifies a "Rural Sky" with low light pollution. Observing in such conditions is ideal for this research, as it ensures the detected Syafaq decay is dominated by natural atmospheric scattering rather than artificial light interference, providing high-fidelity data for color transformation analysis [13].

2.2 Region of Interest (ROI) and Statistical Analysis

Instead of analyzing the entire frame, which may contain terrestrial noise, a fixed Region of Interest (ROI) of pixels was defined at the center of the horizon. For every image in the time series, we calculated the Mean Pixel Intensity for each channel within the ROI. This statistical averaging reduces sensor noise and provides a stable value for tracking the twilight decay.

2.3 Color Transformation and Feature Extraction

While conventional astrophotography relies on the RGB color space, it often fails to isolate specific chromatic shifts. We compared three transformations: YUV, YCbCr, and L*a*b. The analysis focused on identifying the "inflection point" where the chromatic signal of *Syafaq Ahmar* in YUV, YCbCr, and L*a*b stabilizes into the night-sky baseline. This approach validates the method as device-agnostic, as it focuses on color-vector decay rather than absolute luminance.

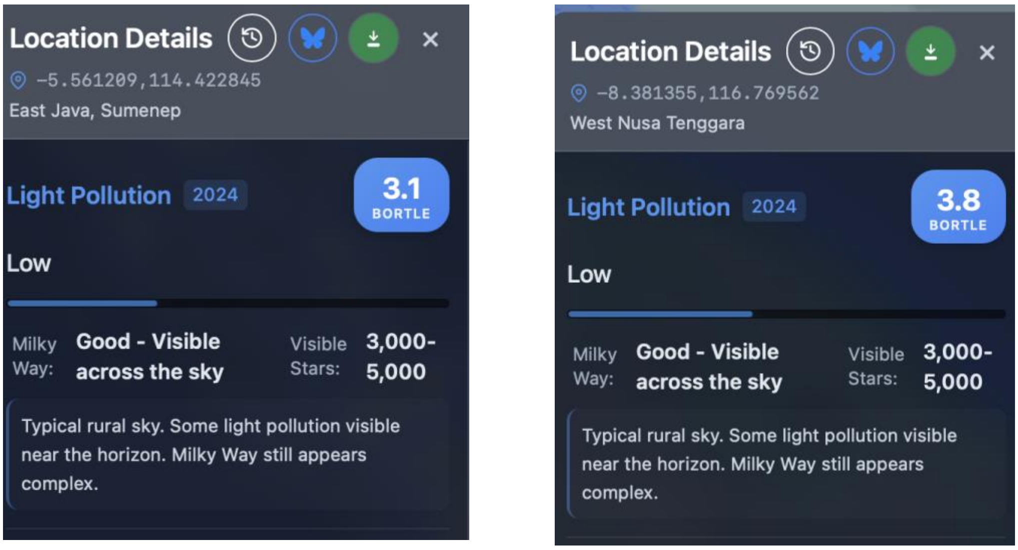

Figure 2. Visual representation of sky quality at the observation sites based on the Bortle Scale [14]

2.4 *Validation Against Official Schedules*

The results were validated by comparing the detected "chromatic disappearance" time (t_{obs}) against the official Isha' schedule from the Ministry of Religion (Kemenag) (t_{ref}). The compliance was measured using the Error Margin:

$$(\Delta \boldsymbol{t} = t_{obs} - t_{ref})$$

This quantitative comparison determines whether the color transformation method aligns with the jurisdictional and astronomical standards of prayer time determination.

Table 1: Sensor Specifications and Data Acquisition Parameters

Parameter	Sensor A (Lombok)	Sensor B (Masalembu)
Device Model	Huawei BAH3-W59	Infinix X670
Aperture	f/2.0	f/1.6
Focal Length	2.48 mm	4.11 mm
ISO Range	50 – 2500	840 – 6400
Exposure Time	0.006s – 0.083s	Fixed 0.069s
Observation Date	Dec 9, 2021	June 28, 2022

3. RESULT AND DISCUSSION

The signs of the start of prayer are determined by the position of the sun. The disappearance of *syafaq* also happens because of the position of the sun after sunset.

According to previous studies, there are two types of *syafaq*, namely *syafaqul ahmar* (red) and *syafaqul abyadh* (white) [15]. The disappearance of the yellowish-red color as a sign of the end of the Maghrib prayer time and the start of the Isha time is quite easy to observe. *Syafaq Ahmar* appeared before *Syafaq Abyadh*. *Syafaq Ahmar* is a reddish phenomenon in the sky that begins at sunset. If the reddish light disappears, there remains what is called *syafaq abyadh* or the end of two *syafaq*.

The astrophotography technique was introduced to analyze the loss of *syafaq* rays. The image data obtained from this technique is a collection of pixels containing a variety of information that can be used for qualitative and quantitative analysis. This is done to avoid the subjectivity of the research. The small differences between sequential photos that cannot be observed by the human eye can be identified through image processing.

In this study, the use of various color space transformations is proposed to enhance the detection of this transition by isolating chromaticity from luminance. The primary objective is to evaluate and determine which color space model provides the highest precision in detecting the disappearance of *Syafaq* rays as the definitive marker for the beginning of Isha' time. The analysis focuses on two main areas: the qualitative observation of sequential images after transformation and the quantitative evaluation of pixel changes visualized through collective curve graphs**.**

3.1 Astrophotography Imagery Color Space Transformation

Color space transformations are used for analysis because discoloration in astrophotography imagery is difficult to identify with the human eye. The various color spaces used are YUV color space, YCbCr color space, and color space L*a*b*. Generally, the results of image data from the camera use the RGB color space model, which is the result of a mixture of primary colors, namely red, green, and blue. Transforming color space needs some equations.

Isha' is physically marked by the disappearance of *Syafaq Ahmar* (reddish twilight), followed by the fading of Syafaq Abyadh (whitish twilight) [15]. While human observation is limited by subjective visual thresholds, image processing provides a quantitative pixel-based baseline. In this study, we transformed the raw RGB data into YUV, YCbCr, and L∗a∗b∗ to identify the most sensitive indicator for this transition. Image transformation from RGB space into a YUV space is described in equation (1)[16]:

$$\begin{aligned} Y &= 0.299*R+ 0.587*G+0.114*B \\ U &=-0.147*R -0.289*G+ 0.436*B \\ V &=0.615*R -0.515*G-0.100*B \end{aligned} \quad (1)$$

R, G, and B are the pixel values of the red (R), green (G), and B (Blue) image. Equation (2) is used for the RGB to YCbCr transformation [16], [17] :

$$\begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 0{,}279 & 0{,}504 & 0{,}098 \\ -0{,}148 & -0{,}291 & 0{,}439 \\ 0{,}439 & -0{,}368 & -0{,}071 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (2)$$

The color space transformation from RGB to L*a*b* cannot be converted directly. The RGB color space needs to be converted to the XYZ color space by the XYZ color space, and then the XYZ color space is converted to the L*a*b* color space. RGB has the following relationship with the XYZ color space:

RGB has the following relationship with the XYZ color space [18]:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0{,}412453 & 0{,}357580 & 0{,}180423 \\ 0{,}212671 & 0{,}715160 & 0{,}072169 \\ 0{,}019334 & 0{,}119193 & 0{,}950227 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (3)$$

After conversion, the L*a*b color space value can be calculated:

$$L^* = \begin{cases} 116\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - 16 \; if \; \left(\frac{Y}{Y_n}\right) > 0{,}008856 \\ 903{,}3\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} \quad if \; \left(\frac{Y}{Y_n}\right) \leq 0{,}008856 \end{cases} \quad (4)$$

$$a^* = 500\left[f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right)\right] \quad (5)$$

$$b^* = 200\left[f\left(\frac{Y}{Y_n} - f\,\frac{Z}{Z_n}\right)\right] \quad (6)$$

X_n, Y_n, and Z_n have values in equation (7) and f_u in equation (8).

$$[X_n \; Y_n \; Z_n] = [0{,}950450 \;\; 1{,}00000 \;\; 1{,}088754] \quad (7)$$

$$f_u = \begin{cases} u^{\frac{1}{3}} & if \; u > 0{,}008856 \\ 7{,}778u + \frac{16}{116} & if \; u \leq 0{,}008856 \end{cases} \quad (8)$$

Figure 3 and Figure 4 are part of the astrophotography imagery before *syafaq* rays rise and disappear. The difference between Figure 3 and Figure 4 is only the difference in data location. Figure 3 image data in Figure 3 was taken in Masalembu, and in Figure 4 the image was taken in Lombok Island.

The purpose of this color transformation is to analyze the disappearance of *syafaq* more easily. Using the color image transformation will provide deeper analysis. Figures 3 and 4 demonstrate the chromatic transition captured through image processing, tracking the sequence from the initial appearance of *Syafaq* rays until their complete disappearance. Based on the data taken that shown in Figure 3 and Figure 34 it is observed that the L*a*b* color model tends to be more sensitive than all other color transformation models. This result shows that the color space transformation will make a more detailed analysis from one image to another.

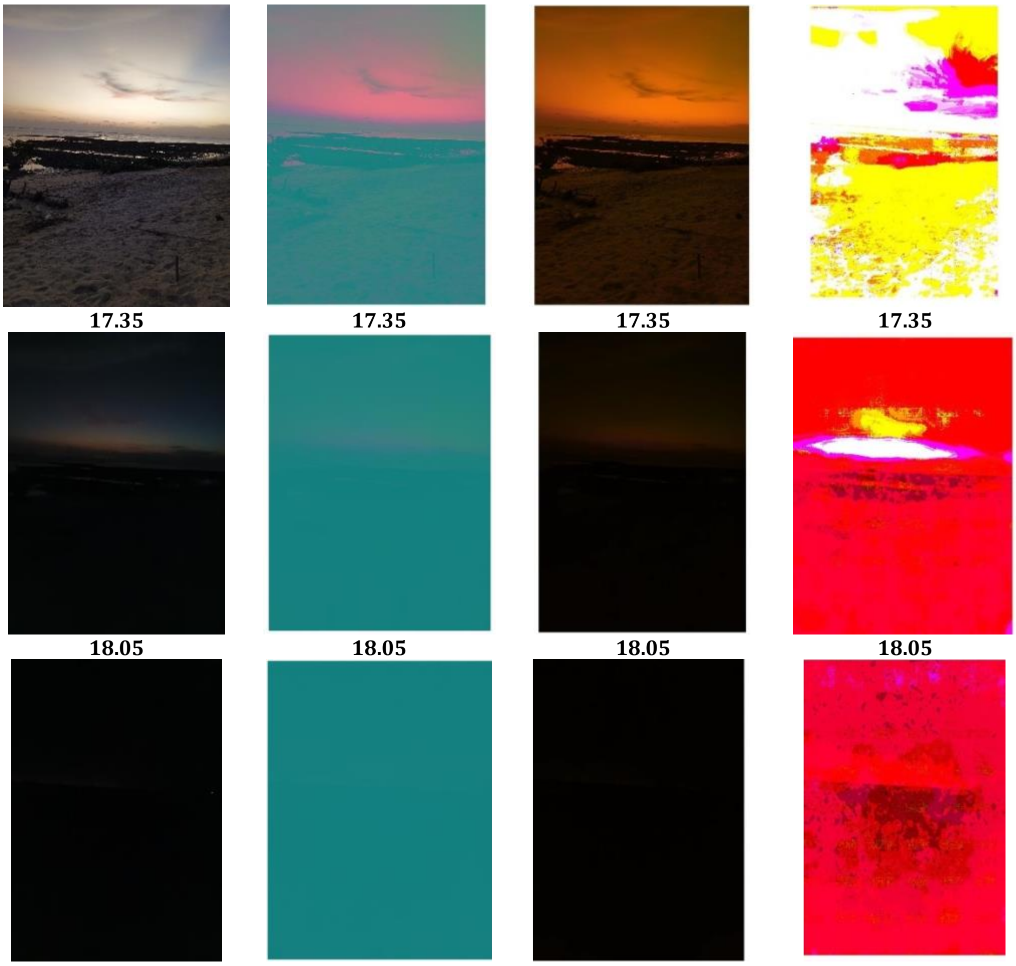

Figure 3. Timelapse colorspace transformation from the beginning until the disappearing syafaq in Masalembu

The L*a*b* color model in Figure 3 and Figure 4 clearly shows the timelapse of astronomical phenomena at sunset than in other colorspaces. Starting from the image that syafaq is brightly colored, it slowly turns yellow, and finally, the syafaq disappears. The results of this color transform analysis indicate that the color space transformation method can be used for syafaq ray analysis. To simplify the analysis, the changes in pixels between images are collected in a collective curve to determine the changes in pixels when the syafaq rays begin to disappear.

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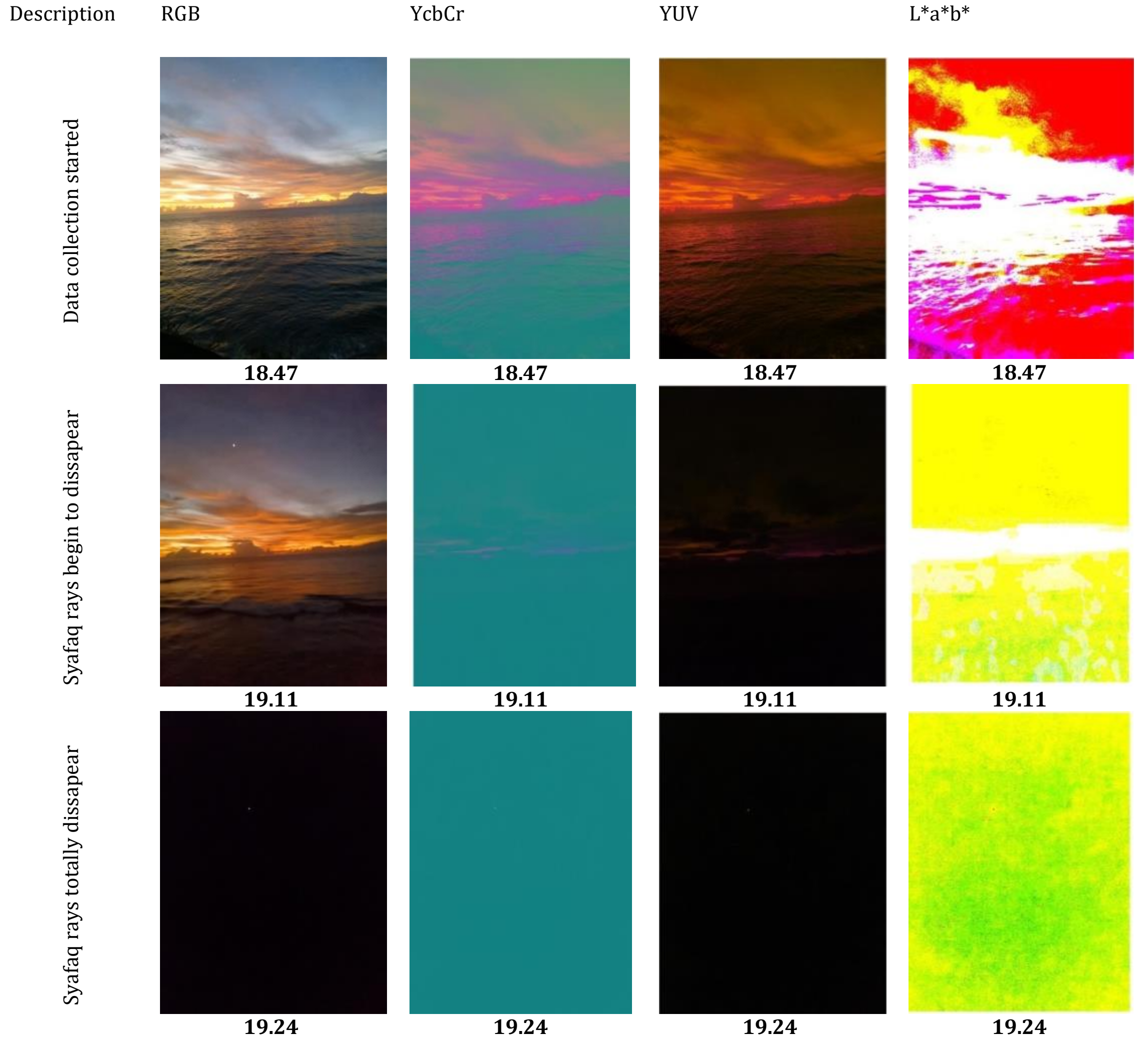

Figure 4. Timelapse colorspace transformation from the beginning until the disappearing syafaq in Lombok.

As shown in Figure 3 (Masalembu) and Figure 4 (Lombok), the color model demonstrates superior sensitivity compared to the other models. Specifically, the channel in the space—which represents the chromaticity axis between red and green—effectively isolates the "chromatic decay" of the sunset. While (luminance) channels only track the overall decrease in light intensity, the model captures the qualitative shift from yellowish-red to the deep blue of the night sky. This proves that color space transformation provides a more detailed, "frame-by-frame" astronomical analysis that is otherwise invisible to the naked eye.

The superior sensitivity of the model is primarily due to the _*a* channel, which effectively isolates the 'chromatic decay' (red-to-green axis)_ of the sunset. While luminance-based channels (Y) in other models only track total light intensity, the space differentiates the vanishing reddish hue from the darkening night sky. This provides a 'frame-by-frame' analytical advantage that is invisible to the naked eye. These pixel changes are further aggregated into collective curves to quantitatively determine the precise onset of Isha' time.

Although this is a preliminary study involving two observation sessions, each session provided a dense temporal resolution with 1-minute sampling intervals. This high frequency allows for a precise mapping of the L∗a∗b∗ chromatic decay. The variety in sensor specifications (f/2.0 vs f/1.6) and ISO sensitivities (up to 6400) further validates that the proposed Color Transformation method is device-agnostic, meaning it can reliably detect Syafaq patterns regardless of the specific hardware used.

3.2 Collective Curve

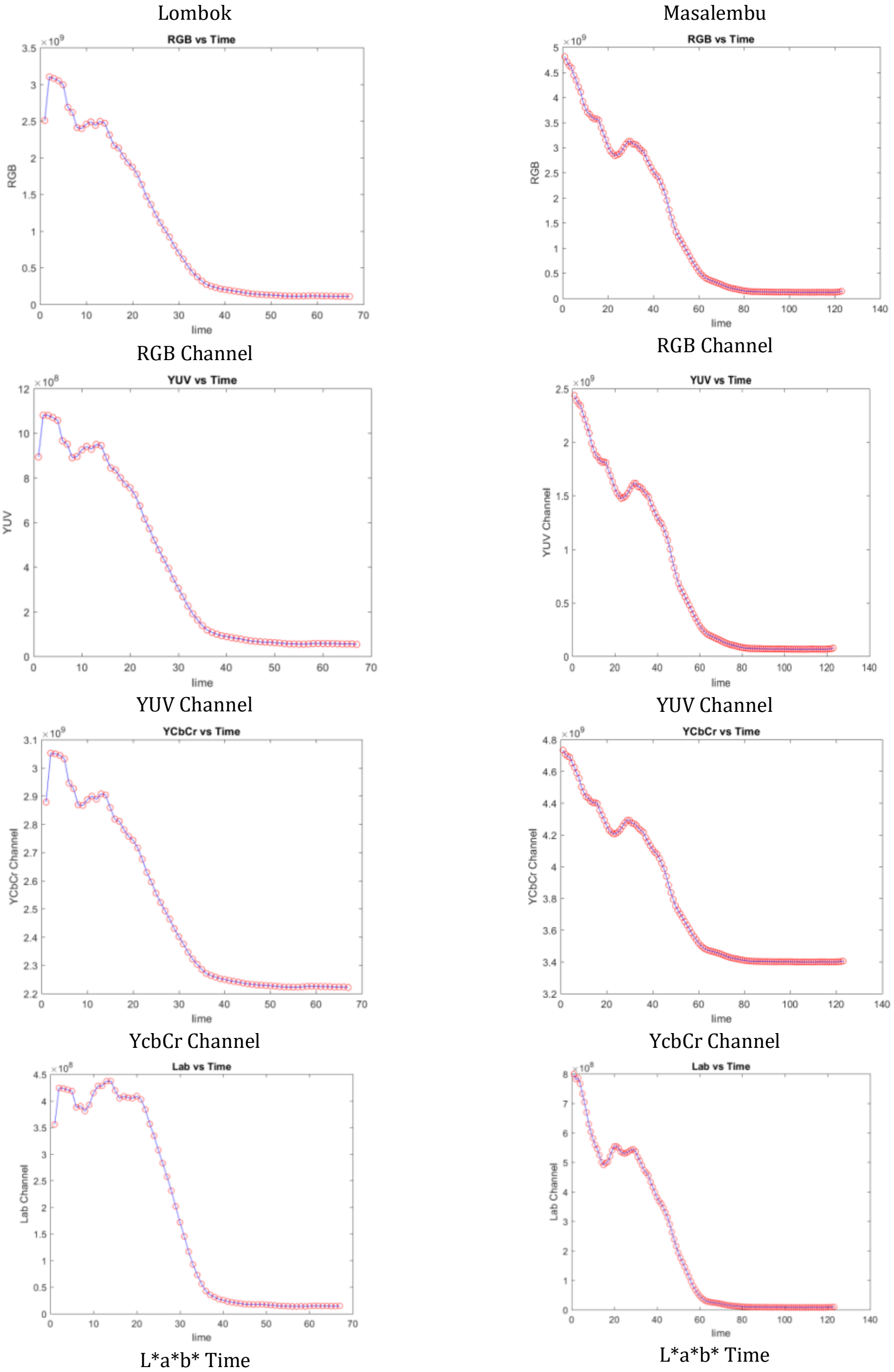

Figure 5. Pixel change graphy typology between Masalembu and Lombok Island

The image data used in this study is sequential and was taken within approximately 90 minutes from before sunrise to sunset. Therefore, we need a visualization that can show changes in light intensity. For 8-bit images in the 0-255 pixel value range, the brighter the image, the higher the value. Based on this theory, a cumulative curve is shown to facilitate the analysis of syafaq as the beginning of Isha' time.

Figure 5 is the change in pixels from before and after the *syafaq* ray rises. The x-axis is a sequence of images, while the y-axis is the pixel value in each color space. The right column is the Lombok typology graphic of pixel changes, while on the left is the Masalembu typology. It can be observed that the graphic typology on the 4 channels is almost the same, but with different Y-axis values depending on the color space. Also, the different location and the different camera do not change the graphic typology. This shows that the overall color space can identify changes in intensity due to the loss of *syafaq* rays.

The number of pixels only shows detailed image information; the graphic typology of each color space is analyzed further because it shows the process of decreasing or increasing light intensity. The change in pixels for both Lombok and Masalembu shows that despite the use of different hardware (Huawei vs Infinix) and different seasonal data (December vs June), the graphic typology remains consistent. This suggests that the overall color space transformation can reliably identify intensity changes regardless of the specific camera sensor used, proving the method to be device-agnostic.

3.3 Validation and Comparison with Isha Prayer

Table 2. Pixel change graphy typology between Masalembu and Lombok Island

Location	Kemenag Isha' Prayer	Result of this Research
Masalembu	18.35 WIB	18.38 WIB
Lombok	19.22 WITA	19.21 WITA

Analysis of the identification of the disappearing Syafaq is carried out in two ways: first, by observing the color space transformation sequences (Figure 3 and Figure 4), and second, by analyzing the quantitative pixel changes through collective curves. This dual-method approach ensures a more robust and objective analysis. The Isha' time in this study is determined by identifying the "inflection point" where the graphic typology begins to flatten (plateau). This flattening indicates that the Syafaq rays have completely vanished and the sky has reached a stable nighttime baseline intensity. Table 2 presents the comparison between the detected results from this study (t_{obs}) and the official Isha' prayer schedule from the Ministry of Religion (t_{ref})

As shown in Table 2, the observed time difference (Δt) ranges from 1 to 3 minutes. From an astronomical perspective, this discrepancy is considered acceptable as it is influenced by local atmospheric extinction and aerosol optical depth [19]. In the context of Islamic jurisprudence (Fiqh), this margin falls within the *Ihtiyati* (precautionary buffer) typically employed by the Ministry of Religion [20], [21]. These findings suggest that current concerns or issues regarding the need to significantly correct Isha' prayer times may not be entirely justified, as this empirical data demonstrates results that are closely aligned with the Ministry of Religion's schedule. However, it is important to emphasize that this study is strictly a scientific contribution focused on image processing and astronomical observation. While this research provides empirical evidence to support the accuracy of existing schedules, the final decision regarding prayer time regulations remains within the jurisdiction of Fiqh experts and religious authorities, rather than the researchers

While this study is currently limited to geographical locations, the consistency of the chromatic decay patterns across two different latitudes and seasons (December and June) provides a strong proof-of-concept. This indicates that the color space transformation method possesses significant potential for broader generalization as an objective, sensor-based tool.

The availability of adequate data and instruments, both in quality and quantity, is a challenge in this research. Therefore, the contribution is still very open to completing the preliminary studies in this research.

4. CONCLUSION

This research demonstrates that image processing, specifically color space transformation, is an effective method for analyzing the presence of *Syafaq Ahmar*. Based on the comparative analysis, the *Lab color space, specifically the *a* -channel*, yielded the most precise results in tracking the redness pattern of twilight. Quantitative validation shows that the detected beginning of Isha' time differs by approximately 3 minutes compared to the official Ministry of Religion (Kemenag) schedule. The collective intensity curves further support this by illustrating a clear transition from twilight decay to the night-sky baseline. Consequently, this transformation method serves as a viable quantitative alternative for determining prayer times. Future research will build upon these extracted features to implement Machine Learning algorithms for fully automated Isha' time detection across diverse atmospheric conditions.

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