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DIY photometer in determining the beginning of dawn time in Cimahi City

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ABSTRAK

The use of SQM as a calibrated portable photometer is currently a hot topic in astronomical research in terms of measuring the brightness of the night sky; DIY Sky Quality Meter (SQM) with the name Photometer D.I.Y – CJ'01 has been successfully made and tested on a limited basis, the output data obtained by the photometer This is the magnitude value per square arc second (mag/sq arc second ~ mpsas). This research aims to determine the performance of the D.I.Y - CJ'01 Photometer in measuring the night sky's brightness to determine the start of dawn. The research method used was an experiment with data collection from the D.I.Y Photometer – CJ'01 and SQM Unihedron in Cimahi City during the New Moon and Full Moon. The results of data processing using the solver method show that the D.I.Y - CJ'01 Photometer has almost the same performance as the SQM Unihedron based on the inflection point value that determines the start of dawn and also indicates the existence of pseudo-night in the city of Cimahi which is by typical urban areas dominated by light pollution and air pollution.

Keywords: Dawn Time, DIY, Photometer

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INTRODUCTION

As is known, the agreed dawn time in Indonesia is when the sun is at -20 degrees, but in recent years, the issue has reappeared, stating that dawn time is too early. This issue re-emerged from several studies and research articles in proceedings, journals, and books (Rakhmadi et al., 2020; Yazid Raisal et al., 2019; Saksono, 2017). The study's results placed the sun at a depth of 18 degrees. The government then, through the Ministry of Religion, re-measured the dawn time in locations far from light pollution, namely Labuan Bajo Beach and Mount Timau, finding that the depth of the sun at dawn was -19.5 degrees which was then raised to -20 degrees (Amin, 2020; Setyanto, 2021).

In Islam, based on fiqh studies, there are two fajr types: fajar kadzib (false) and fajar shadiq (real). Fajr kadzib usually comes early to decorate the eastern sky with a weak intensity that resembles a triangle or a wolf's tail that rises along the ecliptic line, which comes from interplanetary dust exposed to sunlight to produce a weak light known as zodiacal light then fajar shadiq appears slowly from the horizon horizontally until it gets brighter and brighter which comes from the position of the sun that moves up to the horizon (Setyanto et al., 2021), The appearance of Fajar Sadiq is then used as a sign of the entry of dawn for prayer and fasting, this is based on various studies from the Koran, and historical traditions studied in fiqh (Herdiwijaya, 2020).

Meanwhile, in astronomy, dawn is a phenomenon that describes a transition from night to day, where the sun begins to creep up towards the horizon. In the process of crawling up, dawn is then divided into 3 phases of dawn based on its position: astronomical dawn, nautical dawn, and civil dawn. At astronomical dawn, the sun is at a depth of -18 to 12 degrees below the horizon, where the sky is still dark, so any object is difficult to recognize or see. Nautical dawn is when the sun is at a depth of -12 to -6 degrees, where the sky is still dark enough so that conditions are still dimly lit, causing the objects seen to be still blurry. Meanwhile, the civil dawn of the sun is at a position of sun depth of -6 to -0.5 degrees, where the scattering of sunlight is starting to be strong enough to give the eye the ability to recognize an object or various objects (Herdiwijaya, 2017).

Therefore, knowing the beginning of dawn with the naked eye is very difficult; a sensitive tool is needed to measure changes from dark to light to indicate the start of dawn (Barbur & Stockman, 2010). The tool is a photometer, a device used to measure lighting or irradiation, which detects the intensity of light scattering, absorption, and fluorescence (Ohno et al., 2020). Most photometers are based on photoresistors or photodiodes, where electrical properties change when light is irradiated, which can then be detected by specific electronic circuits (Yurish, 2005). The Sky Quality Meter from the Unihedron company from Ontario, Canada, uses a TSL237 sensor to convert light into frequency.

This Unihedron Sky Quality Meter (SQM) photometer has a CM500 HOYA filter with a spectral range between 300-720 nm (500 nm peak), which means the SQM detector response is equal to the visual spectral sensitivity of the human eye (Ngadiman et al., 2020). There is a TSL237 sensor that converts light to frequency; TSL237 combines a silicon photodiode and a current-to-frequency converter on a single monolithic CMOS integrated circuit; the output is a square wave with a frequency directly proportional to the light intensity (irradiance) on the photodiode (Hänel et al., 2018). Around 2005, Cinzano, through a research report related to night sky photometry, used the Unihedron Sky Quality Meter (SQM) photometer, which is low-cost and small and very easy to use (point the photometer at the peak, press the button and read the data on the screen), but still accurate enough to carry out scientific research in measuring the brightness of the night sky (Cinzano, 2005).

The TSL237 sensor is also embedded in the D.I.Y-CJ'01 Photometer. It has been successfully made using the Arduino nano microcontroller (Asmoro et al., 2022), which is equipped with an LCD screen to display measurement results and a time display with a real-time clock (RTC) module, as well as a data logger to store measurement results including internal power sources that are packaged in one tool into more value that distinguishes it from the existing unihedron SQM variants (Figure 1). SQM Unihedron and D.I.Y-CJ'01 measured in the astronomical magnitude system mag/arcsec^2 (magnitude per square arc second), the basis of which is that if an area of the sky contains exactly one star of magnitude X in every square arc second, then the brightness of the sky is X mag/arcsec^2 (Hearnshaw, 2022). The magnitude system was introduced by an ancient Greek astronomer named Hipparchos, who assigned magnitude 1 to the brightest star visible to the naked eye and magnitude 6 to the faintest star visible to the naked eye, noting that light pollution was not yet dominant at that time (Cunningham, 2020; Kaltcheva & Berry, 2023).

(a) (b)

Figure 1. (a) Photometer DIY-CJ01, (b) SQM Unihedron LU-DL

The utilization of SQM in determining the time of dawn has been done by several researchers (Affendi et al., 2021; Musonnif, 2022; Putraga et al., 2022; Raisal et al., 2019; Saksono et al., 2020), the new thing that will be done in this study is the utilization of photometer tools that have been made independently and different data analysis techniques using solvers. This article will explain the process of collecting and processing sky brightness data in determining the start of dawn using the turning point approach obtained from photometers, both SQM Unihedron and D.I.Y-CJ'01. The results also test the performance of the D.I.Y-CJ'01 Photometer as a measuring instrument suitable for use as an alternative photometer for observing the night sky's brightness.

RESEARCH METHODS

The research method used is the Experimental Method, the DIY CJ'01 Photometer simultaneously with a calibrated SQM Unihedron photometer, which is then used to measure the night sky's brightness from 00.00 WIB to 06.00 WIB. This test was carried out in Cimahi City during the New Moon and Full Moon phases, as seen in Figure 2. The pattern formed during the transition from night to morning is characterized by a decrease in the measured MPSAS value so that if displayed in the graph, a straight line pattern will be seen and then turn downward over time. The reversal process is said to be the beginning of dawn, so by analyzing the turning point, we will get the value of the start of dawn (Rizkiawan et al., 2021), and the turning point determination results from the two nights will be compared to see if the performance of the DIY-CJ01 Photometer (CJ01) is the same as the SQM LU-DL Unihedron

(SQM).

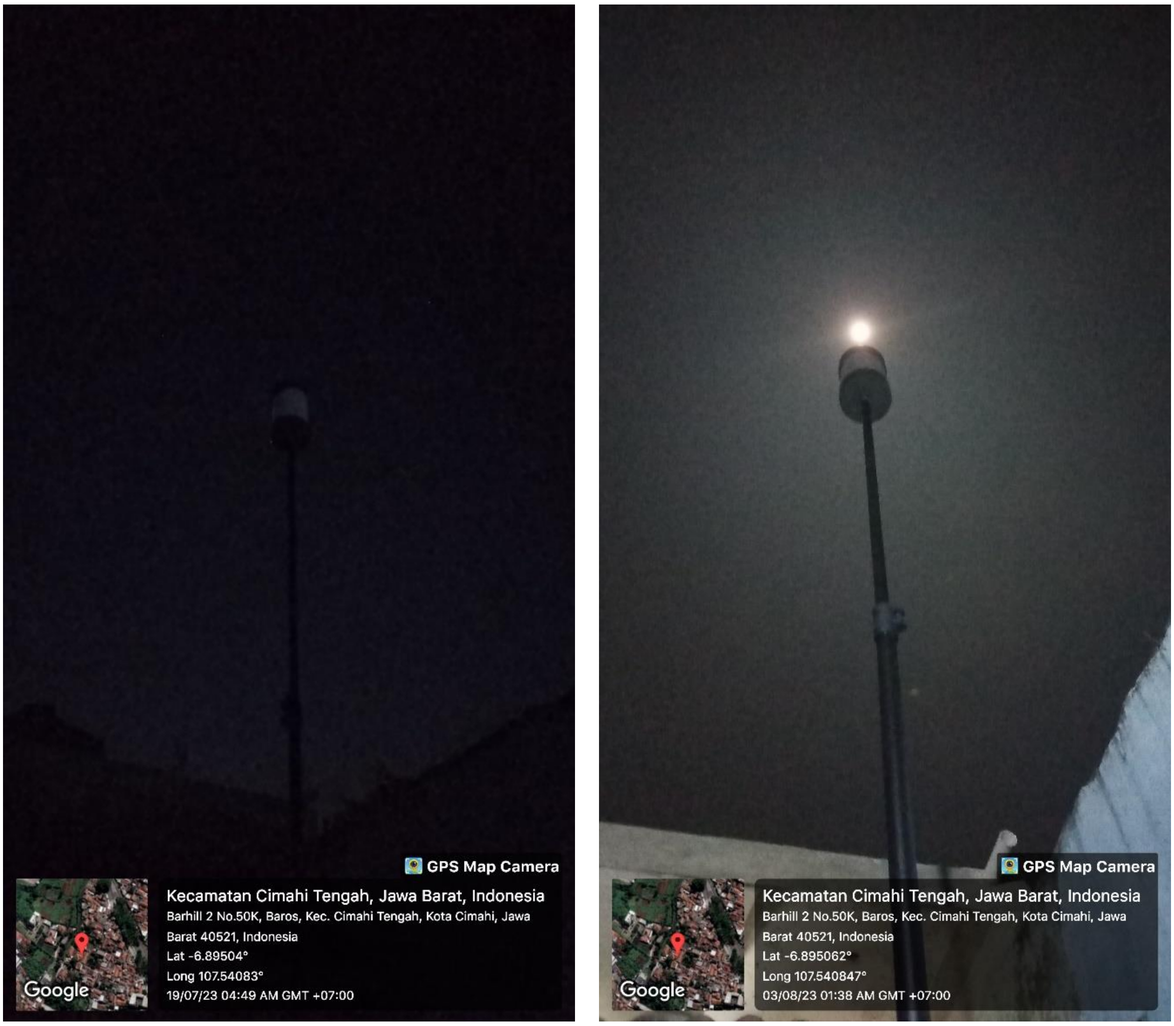

Figure 2. Location and data collection set in Cimahi City

The work steps in this research are as follows:

a. Photometer Installation
b. Set the time to measure the brightness of the night sky every 5 seconds
c. Download night sky brightness data
d. Create a table containing the time and mpsas values
e. Graph plot of mpass value against time
f. Convert the time column to a solar depression angle (https://www.esrl.noaa.gov/gmd/grad/solcalc/NOAA_Solar_Calculations_day.xls)
g. Determining Inflection Points with the Solver Method in Microsoft Excel software.
   i. Arrange a table with the first column being the sun's depth angle from -25 to -5 degrees, followed by the next column containing the MPSAS value from the measurement results and the MPSAS value from the m(x) model, respectively.
   ii. The m(x) model has a formula consisting of constant level, normalization, mean, and standard deviation, as a Gaussian function.
   iii. Looking for the best model parameters by minimizing these parameters with Solver.
   iv. Determine several n standard deviations consistently to obtain three inflection point

values.

v. A graph of the sun's depth angle with MPSAS values is plotted, which displays three turning points to determine the start of dawn time.
vi. Select the Data menu in Microsoft Excel, then click Solver.
vii. Select Min and GRG Nonlinear, then click Solve.
viii. Select Keep Solve Solution, then click OK.
ix. Calculate the difference in 3 inflection point values from data generated by SQM and CJ01.

RESULTS AND DISCUSSION

Geographically, the location in Cimahi City is at coordinates 6.894895 south latitude and 107.540804 east longitude, with an elevation of ±777 meters above sea level. Place the two photometers together in one container and store them at a height of ±3 meters because they are located around residential areas to avoid direct light. Sky brightness measurements were carried out on July 19, 2023 (New Moon) and August 3, 2023 (Full Moon), with a photometer directed at the zenith (Herdiwijaya, 2016).

The sky brightness data during the transition from night to morning are presented in Figure 3 and Figure 4, with the horizontal axis being the local time and the vertical axis being the sky brightness value in magnitude per square arc second unit (mag/sq arc second ~ mpsas). There is a similar graphical pattern between the measurements from the SQM and CJ01; in Figure 3, during the new Moon phase, the Moon and Sun are in the same direction of the sky, so the Moon is not visible in the night sky. Hence, the night sky brightness tends to stabilize at 18 mpsas before decreasing slowly as the Sun's light begins to contribute.

In Figure 4, during the Full Moon phase, the Moon is in the sky throughout the night, from rising in the east in the early evening, around the zenith after midnight, and setting in the west. This is recorded in the photometer, which can be seen in the graph where at midnight, the brightness value of the night sky is at a smaller value of about 15 mpsas, then rises to 17 mpsas as the moon is no longer around the zenith where the photometer is pointed and the mpsas value drops again as light from the sun starts to contribute (Ahmed, 2021; Setyanto et al., 2021).

Sky brightness data during the transition from night to morning is presented in Figure 3 and Figure 4, with the horizontal axis being local time and the vertical axis being the sky brightness value in units of magnitude per square arc second (mag/sq arc second ~ mpsas). The same graphic pattern between measurements from SQM and CJ01 can be seen in Figure 3; during the new moon phase, the Moon and the Sun are in the same direction as the sky, so the Moon is not visible in the night sky. Hence, the night sky's brightness tends to stabilize at a value of 18 mpsas before decreasing slowly as a sign that sunlight is starting to contribute.

In Figure 4, during the Full Moon phase, the Moon is in the sky all night, starting from rising in the east at the beginning of the night, being around the zenith after midnight, and setting in the west. This is recorded in the photometer, which can be seen on the graph where at midnight, the brightness value of the night sky is at a smaller value of around 15 mpsas, then rises to 17 mpsas because the moon is no longer around the zenith where the photometer is directed and the value mpsas fell again as light from the sun began to contribute.

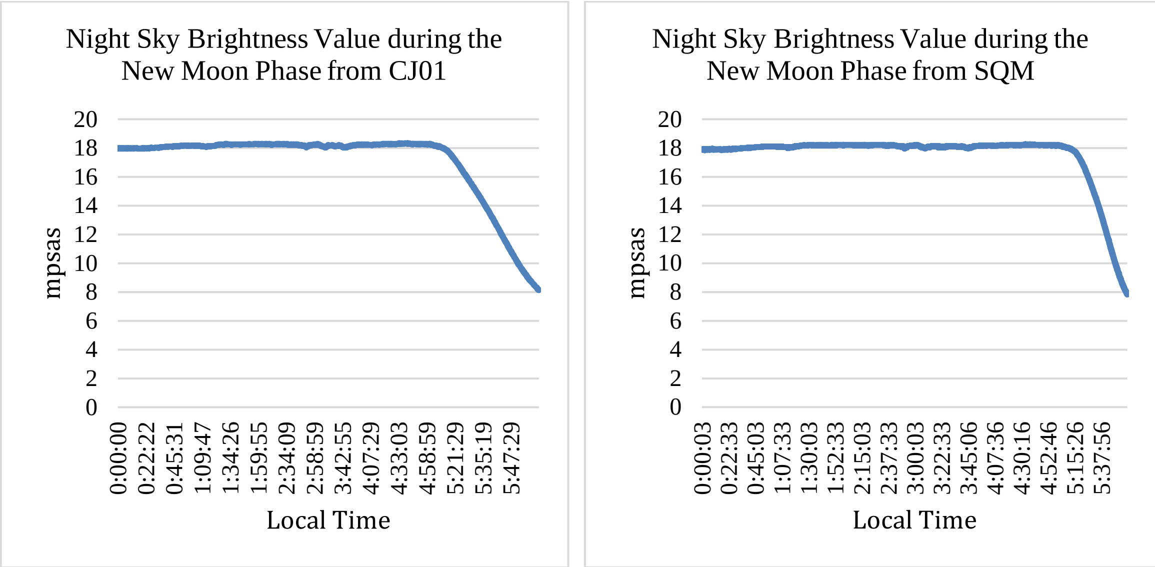

Figure 3. Graph of local time versus mpsas value during the New Moon

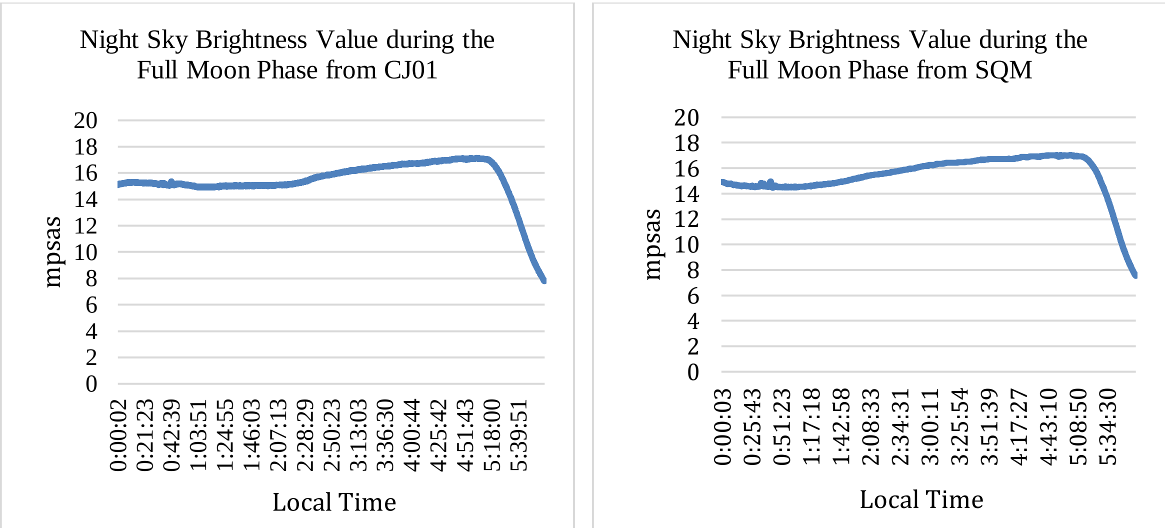

Figure 4. Graph of local time versus mpsas value at Full Moon

To find out the turning point as a determinant of the beginning of fajr time Islamically and astronomically, convert the time variable into an angular variable of solar depth in degrees. Next, choose the range of sun depth position -25 to -5 degrees to make it easier to determine the equation of the graph model formed. Then, we will get a blue graph, the mpsas value of the measurement results, and an orange graph, which is the mpsas value of the modeling results. Then, determine n = 3 consistent standard deviations, consisting of the mean and constant level difference, and display them as three consecutive vertical dashed lines with colors (1) red, (2) green, and (3) blue.

Figure 5 shows the same graphical pattern where the night sky brightness values for solar depth angles between -23 to -17 degrees tend to stabilize around 18 mpsas for both the SQM and CJ01-generated data. Figure 6 also shows a similar graphical pattern for both the data generated by SQM and CJ01, where at sun depth angles of -23 to -15 degrees, the night sky brightness values tend to stabilize at around 17 mpsas. So, it can be seen that the presence of the Full Moon contributes to a decrease in the night sky brightness value by 1 mpsas, and the duration to the initial turning point at dawn is delayed by 2 degrees from the movement of the Sun, this value is different for each measurement location because the moon's trajectory in the sky is different(Cui et al., 2021; Krieg, 2021; Liu et al., 2022).

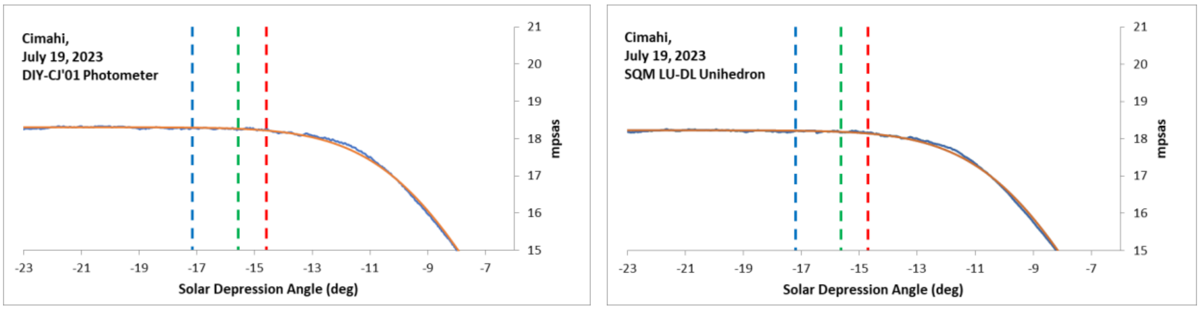

Figure 5. Mpsas value plot as a function of Solar Depression Angle during the New Moon

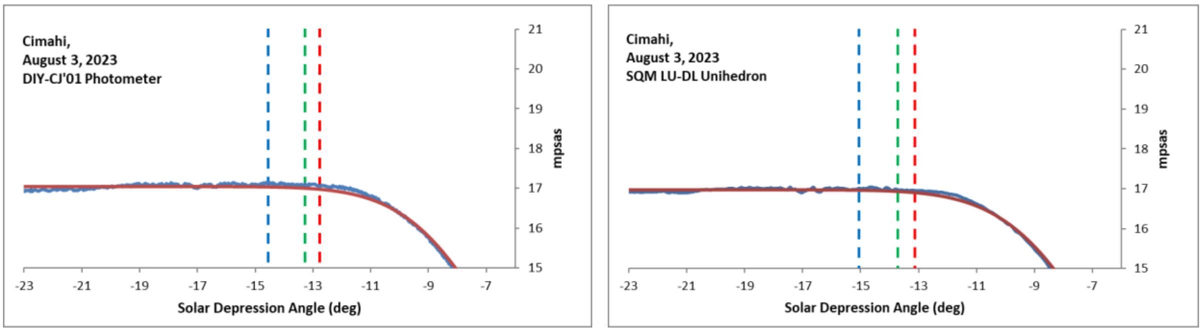

Figure 6. Mpsas value plot as a function of Solar Depression Angle during the Full Moon

Table 1. Differences in calculating the initial turning point at dawn

Moon Phases	Inflection Point	Solar Depression Angle (degree) SQM	CJ'01	Difference (degree)
New Moon (July 19, 2023)	1	-14,69	-14,59	-0,10
	2	-15,62	-15,57	-0,05
	3	-17,19	-17,16	-0,03
Full Moon (August 3, 2023)	1	-13,13	-12,76	-0,37
	2	-13,72	-13,28	-0,44
	3	-15,05	-14,56	-0,50

Table 1 shows the calculation results of 3 inflection points (1) red, (2) green, and (3) blue from the graphs obtained from SQM and CJ01 on July 19 and August 3, 2023. From the calculation results of the turning point difference, it can be seen that SQM tends to turn earlier than CJ01, with the smallest turning point difference occurring at turning point 3 on July 19, 2023, which is -0.03 degrees or about 0.17% and the largest difference at turning point 3 on August 3, 2023, which is -0.50 degrees or about 3.2%. The significant difference at the turning point on August 3, 2023, is due to the contribution of the Full Moon moving across the zenith with a maximum height of 79 degrees in the southern sky region.

As discussed in the introduction, the standard for the height of the sun at dawn prayer time in Indonesia, the ijtihad used is the position of the sun - 20 degrees (below the horizon), with the basis of shar'i and astronomical arguments that are considered vital (Budiwati, 2018). In astronomical science, the beginning of dawn starts from an angle of the sun's depth of -18 degrees, called astronomical dawn. However, from processing the data obtained in both the New Moon phase and the Full Moon phase, it was found that the turning point value determining the start of dawn ranged from -12.76 to -15,05 degrees for Full Moon and -14.59 to -17,19 degrees for New Moon. This indicates that the pseudo-night effect is occurring, namely the condition of small changes in sky brightness due to sunlight being absorbed by pollutant particles originating from air pollution accumulating in the lower atmosphere (Herdiwijaya, 2017). Artificial light emitted from the Earth's surface can also scatter off molecules or aerosols in the atmosphere and return to Earth as "skyglow." In a bright night sky, this results in a loss of star visibility, especially in the region near the horizon; here, the light is brightest (Luginbuhl et al., 2014).

CONCLUSION

Based on observations using two photometers, SQM and CJ01, in Cimahi city, both during the New Moon and Full Moon phases, it shows that both photometers have the same performance. This conclusion is generated by calculating the turning point as the beginning of dawn using the Solver method, showing values close to each other with the smallest calculated difference of -0.03 degrees or 1.7%. It appears that at astronomical dawn -20 to -18 degrees, the sky brightness value is still constant as night while the change in sky brightness occurs at -17 degrees or about 65 minutes before sunrise; at this angle is the beginning of dawn time based on sky brightness data in Cimahi. The observation results show a false night in Cimahi City, a typical urban areas dominated by light and air pollution. These two types of pollution also affect the depth value of the Sun. In addition, measurements during the Full Moon Phase contribute light so that the brightness value of the night sky decreases and the false night effect becomes longer.

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