ZODIAC LIGHT DETECTION BASED ON SKY QUALITY METER (SQM) DATA: PRELIMINARY STUDY

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Abstract

Zodiacal light is a phenomenon that occurs in the sky just before sunrise. This phenomenon is known as the dawn of kadžib in astronomy, the false dawn that precedes the appearance of the dawn of šadīq as a signal of the beginning of the Fajr prayer time. The appearance of the zodiacal light on the eastern horizon can now be detected using various astronomical instruments, one of which is using the Sky Quality Meter (SQM) intensity meter. Observation of the light intensity of dawn at six locations using SQM resulted in a light curve that had similarity. Based on the plot of a number of dawn light curves which are approximated by a linear function in the data range with the Sun’s elevation value less than -20°, it shows that there is a linear pattern that tends to decrease. The linear pattern obtained indicates that the zodiacal light in a light-polluted location can detect its occurrence.

Keywords: fitting linear; dawn light curve; Sky Quality Meter (SQM)

Abstrak


Kata Kuncé: fitting linear; kurva cahaya fajar; Sky Quality Meter (SQM)
A. Introduction

Dawn is one of the natural phenomena that has attracted the attention of mankind since ancient times. The brightness of dawn changes with the zenith distance of the Sun. Astronomy divides dawn into three groups that are affected by the zenith distance of the Sun, namely: Astronomical Dawn (astronomical twilight, Z=108°), Nautical Twilight, Z=102° and Civil Dawn (Civil Twilight, Z=96°). The division is based on the visual appearance of dawn that can be captured by the human eye. Dawn observations are part of astronomical observations. Currently, relatively many observations of dawn in Indonesia are carried out to analyze the problem of the early dawn prayer time. In general, observations are made with the principle of photometry using SQM (Sky Quality Meter) and a photographic camera.

Dawn observations with photometric principles produce light curves. The light curve which is an intensity-time plot becomes a simple analytical tool that is relatively good enough to describe and explain changes in intensity as a function of time. Based on the results of the light curve analysis, information on the light source, and the medium through which we pass, we tried to analyze the light curve obtained from the photometric observations.

The sky brightness light sources captured by the detector (SQM and Photography) can be grouped into: Zodiacal Light, Twilight, stars and light pollution. From the four light sources, the intensity of Zodiacal Light and Twilight changes with time (seems getting brighter). Therefore, by assuming that starlight and light pollution have a constant intensity, the light intensity of Zodiacal Light and Twilight can be known and separated, so that the initial appearance of Twilight can be known by using a linear function approach to observational data which is considered linear.

B. Method

Dawn observations were made at six different locations with different times. Observation data were obtained by using camera (photography) and SQM instruments. The following table shows the location of dawn observations used in this paper.

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The data used in the study is divided into two types according to the source of data acquisition, namely image data and SQM data. The following is a table of data acquisition information used in the study.

### Table 2. Data Resources

<table>
<thead>
<tr>
<th>Location</th>
<th>Resources</th>
<th>Time</th>
<th>Observer / Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mombhul Beach, Gresik</td>
<td>Citra Yes, SQM Yes</td>
<td>03:37:00 - 04:49:00 LT (UT + 7)</td>
<td>Lajnah Falakiyah Nahdhatul Ulama (LFNU) Gresik Hendro Setyanto, M.Si., AR Sugeng Riyadi (CASA Assalaam)</td>
</tr>
<tr>
<td>Labuan Bajo</td>
<td>Citra Yes, SQM Yes</td>
<td>04:32:58 - 05:04:01 LT (UT + 8)</td>
<td></td>
</tr>
<tr>
<td>Imahnoong</td>
<td>Citra No, SQM Yes</td>
<td>No Data</td>
<td>Hendro Setyanto, M.Si.</td>
</tr>
<tr>
<td>Bosscha Observatory</td>
<td>Citra No, SQM Yes</td>
<td>00:00:01 - 06:11:12 LT (UT + 7)</td>
<td>Dr. Dhani Herdiwijaya, M.Sc. Dr. Dhani Herdiwijaya, M.Sc.</td>
</tr>
<tr>
<td>Amfoang</td>
<td>Citra No, SQM Yes</td>
<td>03:30:01 - 05:59:21 LT (UT + 8)</td>
<td></td>
</tr>
<tr>
<td>Sedan, Rembang, Jawa Tengah</td>
<td>Citra No, SQM Yes</td>
<td>03:42:09 - 05:39:58 LT (UT + 7)</td>
<td>Imam Qusthalaani</td>
</tr>
</tbody>
</table>
This paper uses a linear fitting method to the dawn light curve as a result of observations using a camera and SQM. Linear fitting is carried out on data on the intensity of the night sky brightness against the height of the Sun before the alleged appearance of dawn, which has been known so far (−20°). The following is a table of the range of values for h or the angle of elevation of the Sun (°) for linear fittings.

**Table 3. Range of h or Sun Altitude (°) for Linear Fittings**

<table>
<thead>
<tr>
<th>Location</th>
<th>Range of Sun Altitude (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data from Citra</td>
</tr>
<tr>
<td>Labuan Bajo</td>
<td>-25,90 – -21,03</td>
</tr>
<tr>
<td>Imahnoong</td>
<td>No Data</td>
</tr>
<tr>
<td>Bosscha Observatory</td>
<td>No Data</td>
</tr>
<tr>
<td>Amfoang</td>
<td>No Data</td>
</tr>
<tr>
<td>Sedan, Rembang, Jawa Tengah</td>
<td>No Data</td>
</tr>
</tbody>
</table>

The linear fitting method was also carried out by Guo in 2014 to measure the brightness of dawn at the Weihai Observatory of Shandong University, China, so that the distribution of night sky brightness data against the height of the Sun before dawn can be approximated by a linear function. The linear function that has been obtained is a function of the Zodiacal Light which physically increases its brightness linearly.2

**B.1 Fitting Linear Process**

The linear fitting process is conducted by taking a sample of the intensity of the night sky before dawn. The following is a linear fitting process for two image intensity data and six intensity data from SQM measurements.

a. Determine the range of h or sun altitude (°) for linear fittings. The range of h values is different for each observation data because each observation data has a different observation time span.

b. After determining the range of h for each observation data, then linear fitting is done with the basic equation f(x) = ax + b. The fitting process is carried out using GNUPlot software version 5.2 patch level 8. Statistical information used is linear function, R2, average, and standard deviation. If the distribution of data has a tendency to decrease or increase, then

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2 Guo et al.
the linear equation from the fitting results is used. However, if the data distribution has a flat tendency, then the linear equation used is \( f(x) = \text{average} \).

c. The linear equation along with the standard deviation that has been obtained is then plotted with the overall data. The analysis is done by looking at the distribution of the data around the linear function or the Zodiacal Light function along with the standard deviation \( f'(x) = ax + b \pm \). If there is a datum that has an intensity value of \( i \) (standard deviation) for SQM observations or \( i \) (standard deviation) for image observations from the Zodiacal Light function, then the datum is confirmed to be a combination of Zodiacal Light brightness and dawn. Thus, the beginning of the appearance of dawn can be determined.

C. Results

C.1 Dawn Light Curve at Mombhul Beach, Gresik

Dawn light curve at Mombhul Beach, Gresik, consists of two kinds based on the data source. The first light curve is the average light intensity curve from the image data and the second light curve is the light curve from the SQM data. Here's the curve of the dawn light at Mombhul Beach.

![Figure 1. Average Intensity Light Curve (Citra)](image-url)
C.2 Dawn Light Curve at Labuan Bajo

The dawn light curve in Labuan Bajo consists of two categories based on the data source. The first light curve is the average light intensity curve from the image data and the second light curve is the light curve from the SQM data. The following is the curve of the dawn light in Labuan Bajo.
The dawn light curve at Imahnoong Observatory is the light curve from SQM data. Here's the curve of the dawn light at Imahnoong.

The dawn light curve at Bosscha Observatory is the light curve from SQM data. Here's the curve of the dawn light at Bosscha Observatory.
C5  Dawn Light Curve at Amfoang

The dawn light curve at Amfoang is the light curve from SQM data. Here's the curve of the dawn light at Amfoang.

C6  Dawn Light Curve at Sedan, Rembang, Central Java

The dawn light curve at Sedan, Rembang, Central Java is the light curve from SQM data. Here's the curve of the dawn light at Sedan, Rembang, Central Java.
D. Discussion

D.1 Zodiacal Light Functions

Based on the results of the linear fitting analysis, the zodiacal light function is obtained from the image data and SQM. The zodiacal light function is a mathematical function of the dawn intensity data which can be fitted with a linear function. Fittings with linear functions are used if the data obtained has an intensity that tends to decrease or increase. If the data obtained shows that the intensity tends to be flat, then fitting is done with $i_{ZL}(h) = \text{the average value of the linear function fitting sample}$. The following is a table of the zodiacal light functions as a result of fitting with a linear function.

**Table 4. Zodiacal Light Function**

<table>
<thead>
<tr>
<th>Location</th>
<th>Zodiacal Light Function</th>
<th>Dawn Appearance (Sun Altitude)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Citra</td>
<td>SQM</td>
</tr>
<tr>
<td>Mombhul Beach, Citra SQM</td>
<td>$i_{ZL}(h) = 0.21h + 36.61$</td>
<td>$i_{ZL}(h) = -0.0194h + 21.22$</td>
</tr>
<tr>
<td>Gresik</td>
<td>$R^2 = 0.70$</td>
<td>$R^2 = 0.84$</td>
</tr>
<tr>
<td>Labuan Bajo, $i_{ZL}(h) = 0.03h + 20.65$</td>
<td>$i_{ZL}(h) = -0.0074h + 21.08$</td>
<td>$R^2 = 0.67$</td>
</tr>
<tr>
<td>Sedan, Rembang, Central Java</td>
<td>-</td>
<td>$i_{ZL}(h) = -0.0079h + 20.43$</td>
</tr>
<tr>
<td>Bosscha</td>
<td>-</td>
<td>$i_{ZL}(h) = 0.0018h + 21.12$</td>
</tr>
<tr>
<td>Observatory</td>
<td>-</td>
<td>$i_{ZL}(h) = 19.6419$</td>
</tr>
<tr>
<td>Imahnoong</td>
<td>-</td>
<td>$i_{ZL}(h) = 22.5965$</td>
</tr>
<tr>
<td>Amfoang</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Based on Table 4, it is clear that the appearance of dawn is a marker of the combination of the intensity of the zodiacal light with the intensity of dawn. With a linear approach, it can be known when the dawn appears by comparing the intensity value with the standard deviation of the linear function or the zodiacal light function. Table 4 shows that from photographic observations (Citra), the initial appearance of dawn is on h on average -19.61°. In contrast to the results from SQM observations, the early appearance of dawn is on h on average -17.49°. The difference in the value of h is due to the unequal location of observations, where for photographic observations, it is carried out in locations that are not polluted by light, while SQM observations are also carried out in locations that are polluted by light. If the initial appearance of dawn in Labuan Bajo and Mombhul Beach with SQM observations is averaged, then the value of h is -19.14°. The results of our study differ from those of Semeida et al. (2018) which states that the appearance of the zodiacal light is when h = -19.71°, while the end of the zodiacal light is when h = -14.59°. By looking at the results of the dawn twilight light curve pattern and the appearance of the zodiacal light, it shows that light pollution, weather, and the position of the tool in data collection greatly affect the early appearance of dawn.

E. Conclusion

Based on the results of the analysis using linear fittings, it is known that the appearance of dawn is a marker of the joining of the intensity of the zodiacal light with the intensity of dawn. By taking a linear approach to the observation data, it can be known when the dawn appears by comparing the intensity value with the standard deviation of the linear function or the zodiacal light function. If the initial appearance of dawn in Labuan Bajo and Mombhul Beach with SQM observations is averaged, then the h value is -19.14°. The results of our study differ from those of Semeida et al. (2018) which states that the appearance of the zodiacal light is when h = -19.71°, while the end of the zodiacal light is when h = -14.59°.

F. Bibliography


Amrulloh, Moh Afif. “Penentuan Awal Waktu Shalat Subuh Menurut Kementerian Agama dan

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