A Sky Brightness Contrast Measurement before Sunrise and after Sunset over a Baghdad Region, Iraq

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Abstract. In this work, an analytical study had been made of sky brightness variations using a photometer of Sky Quality Meter (SQM-LU). The sky brightness measurements were performed in Baghdad city of Iraq (Latitude: 33°20'N, Longitude: 44°23'E, and Altitude: 34m above sea-level). The values of sky brightness level were collected on 27 December 2019 as well as 10 January 2020 at sunrise and sunset. The aim of this research is to study on sky illumination contrast by taking moonlight (moonless/full moon) as a reference source. Additionally is to localize the direction of the sun during both sunrise and sunset. The results indicated that, in case of sunrise and moonless, the sky brightness level was obtained averagely at 13.60 ± 0.26 magnitude/arcsecond² with sun's altitude angle at -9.79° ± 0.12°. While, in case of sunrise and full moon, the sky brightness level was obtained averagely at 12.75 ± 0.25 magnitude/arcsecond² with sun's altitude angle at -8.87° ± 0.11°. Findings also showed that, in case of sunset and moonless, the sky brightness level was obtained averagely at 17.44 ± 0.26 magnitude/arcsecond² with sun's altitude angle at -10.66° ± 0.12°. While, in case of sunset and full moon, the sky brightness level was obtained averagely at 15.69 ± 0.25 magnitude/arcsecond² with sun's altitude angle at -10.25° ± 0.11°. In conclusion, the study shows a correlation between the sky brightness magnitude against sun's altitude angle, moon's phase, and weather conditions as well.

1. Introduction
The astronomers for many decades have been monitoring the night sky brightness at several observatories [1]. The night sky brightness measurements are crucial importance in order to find the site of a new ground-based telescope [2]. Night sky brightness strongly depends, apart from the surrounding light sources, on the meteorological and atmospheric conditions [3]. Atmospheric transparency depends on the amount of suspended particles and water vapor contents in the atmosphere [4]. There are six general factors contributing to the night sky brightness are the integrated starlight within our galaxy, the integrated light from distant galaxies, the aurora, the night airglow, the zodiacal light, and the twilight emission lines [5].

In addition to the light data, several environmental and astronomical conditions are so important. Such as the local time, position, moon's phase, and weather conditions as well. This paper will present a model based on brightness contrast difference between the moon's illumination (moonless/full moon) and its sky background (sunrise/sunset).

1.1. Twilight Phenomena
The light that remains after sunset and appears before sunrise is called the twilight [6]. It is a phenomenon that results from direct and secondary scattering process of the upper atmospheric layers (mesosphere≈ 35km) above the earth's surface. The lower atmospheric layers do not share in the scattering process causing twilight because these layers submerge in the earth's shadow. When the sun
is at 10°-15° below the horizon, the illumination conditions approach that of night. The transition to
night gets complete at a depression between 17° and 19°. If the atmosphere is highly turbid, twilight
continues until 22°-23°. So, the twilight is subject to shift depending on the atmospheric conditions
[4].

1.2. Synthetic Lighting
An often is seen as an improvement in the quality of life and an advance in technology. However, the
use of more lighting harms the local environment. The sky glow during the night due to emanates a
vast amount of light from large cities and urban areas. This in turn covers the dark sky and obscurants
the vision of astronomical objects [7].

1.3. Light pollution
It is associated with many ecological problems. Light pollution depends on the two factors are
scattering particle abundance and light emission [8]. There are two types of light pollution is the
ecological and astronomical. The first one is light pollution that strictly affects wildlife. The second
one is affects on the night sky level [7].

2. Equipment and Methodology
Two detectors, in this work, have been used are the SQM-LU photometer and the human eye, both
represent logarithmic changes [9]. The study not focused onto the light how it happens is only on the
perceived by detector. Moreover, the instrument of computer was used and several software in this
research. The SQM-LU unit was connected to the computer via USB cable. The software is Microsoft
Excel, Knightware SQM Reader, and the Python’s PyEphem astrometry library.

2.1. Procedures of Observation
The sky brightness measurements can be divided into three stages is pre-observation, observation, and
post-observation. The observation procedures have been summarized as flowchart in Figure 1.

![Figure 1. Flowchart of the research methodology](image-url)
2.2. SQM-LU Photometer
In general, the SQM photometers are user friendly and not expensive. It is suitable to studying the sky brightness under very different conditions [10]. The sky quality meter was tested by several studies [11-13]. The aperture of the instrument is 20° and spectral ranges between 320-720nm with output directly in magnitudes per arc second square unit [8]. The small numerical changes in SQM reading represent large changes in the sky brightness [14]. Especially, the type of SQM-LU was adopted for methodology performance in this study and it was chosen due to its photometric unit [15]. It use the standard response curve similar that of the eye [16]. Figure 2 displays the SQM-LU photometer (front and back of unit).

![SQM-LU Photometer](image)

**Figure 2.** Depicts the instrument of Sky Quality Meter (SQM-LU) [15]

2.3. Site of Observation
The SQM-LU photometer was employed to collect the data of sky brightness variations during sunrise and sunset (moonless/full moon). The observation was conducted in Baghdad, Iraq, on 27 December 2019 and 10 January 2020 as shown in Table 1. The geographical coordinates of study region is latitude 33°20ʹ north, longitude 44°23ʹ east, and elevation 34 meter. The site is obstruction-free horizon and without light pollution (artificial lights).

| Date          | Time of Observation | Moon's Phase | Weather |
|---------------|---------------------|--------------|---------|
| 27 December 2019 | Sunrise             | Moonless     | Clear   |
| 27 December 2019 | Sunset              | Moonless     | Clear   |
| 10 January 2020  | Sunrise             | Full Moon    | Clear   |
| 10 January 2020  | Sunset              | Full Moon    | Clear   |

**Table 1. Observation date with cloud classification**

3. Results and Analysis
The data collected using SQM-LU photometer of sky brightness will be presented under the form of numerical data. These data has been calibrated firstly and will be later are displays in form of graphs.
3.1. SQM-LU Calibration

Photoelectric calibration was done at the National Space Agency, optical calibration laboratory, Malaysia. The SQM-LU unit has been exams by checking the readings of standard light source versus readings of our photometer. Figure 3 shows the block diagram for this process.

\[ Y = -2.5 \times \left( \log\left(\frac{X}{0.0084}\right) \right) - 2 \times \log(3600) + 0.0376 \]  

(1)

where: \( X \) is the standard source output (Nits) and \( Y \) is the standard source output (MPSAS). Figure 4 shows the calibration curve in native units (Nits).

Besides that, the following formula has been obtained by the linear fitting that was used for data calibration.

\[ Y_1 = 1.0329X_1 - 0.6605 \]  

(2)

where: \( X_1 \) is the SQM-LU reading (magnitude/arcsecond^2) and \( Y_1 \) is the SQM-LU calibrated output (magnitude/arcsecond^2). The performance of the calibration model and the accuracy of prediction results were evaluated using determination coefficient (\( R^2 = 0.9997 \)).
3.2. SQM-LU Measurements

The SQM-LU was fixed at an angle that the moon is expected to be visible by altitude is almost 5º ± 1º above the horizon [18]. SQM reader software was installed allows to take the readings of the meter automatically [19]. The data was recorded at each five minutes for three hours interval approximately into local time. These data was transformed to spreadsheets after taking into account all the errors using the Microsoft excel software. Furthermore, the calculation of sun altitude has been done using Python's PyEphem astrometry library software.

In addition, the following formulas were used to convert from nL (nanoLambert) unit to magnitude/arcsecond^2 unit, vice versa, respectively [17].

\[
Y_2 = 26.33 - 2.5 \log(X_2) \tag{3}
\]

\[
X_2 = 10^{0.4(Y_2-26.33)} \tag{4}
\]

where: \(X_2\) is the SQM-LU reading in nL and \(Y_2\) is the SQM-LU reading in magnitude/arcsecond^2.

The data of sky brightness calibrated (magnitude/arcsecond^2 and nL) with solar altitude position (degree) on 27 December 2019 at sunrise and moonless will be displayed, as an example, in Table 2.

Table 2. Sky brightness values with sun’s altitude angle on 27 December 2019 in Baghdad, Iraq

| Time of Reading | SQM-LU Calibrated (magnitude/arcsecond^2) | SQM-LU Calibrated (nL) | Sun's Altitude (degree) |
|-----------------|------------------------------------------|------------------------|-------------------------|
| 04:03:54        | 13.63                                    | 1.652E-32              | 31.78 6                 |
| 04:08:54        | 13.64                                    | 1.637E-32              | 30.75 4                 |
| 04:13:54        | 13.62                                    | 1.667E-32              | 29.72 0                 |
| 04:18:54        | 13.65                                    | 1.622E-32              | 28.68 3                 |
| 04:23:54        | 13.61                                    | 1.683E-32              | 27.64 4                 |
| 04:28:54        | 13.60                                    | 1.698E-32              | 26.60 3                 |
| 04:33:54        | 13.59                                    | 1.714E-32              | 25.55 9                 |
| 04:38:54        | 13.62                                    | 1.667E-32              | -                       |
| Time  | Value 1 | Value 2 | Value 3 | Value 4 |
|-------|---------|---------|---------|---------|
| 04:43 | 13.62   | 1.667E-32 | 24.51   | 4       |
| 04:48 | 13.63   | 1.652E-32 | 22.41   | 9       |
| 04:53 | 13.62   | 1.667E-32 | 21.36   | 9       |
| 04:58 | 13.64   | 1.637E-32 | 20.31   | 6       |
| 05:03 | 13.65   | 1.622E-32 | 19.26   | 7       |
| 05:08 | 13.59   | 1.714E-32 | 18.21   | 5       |
| 05:13 | 13.59   | 1.714E-32 | 17.16   | 2       |
| 05:18 | 13.61   | 1.683E-32 | 16.10   | 9       |
| 05:23 | 13.62   | 1.667E-32 | 15.05   | 5       |
| 05:28 | 13.61   | 1.683E-32 | 14.00   | 1       |
| 05:33 | 13.59   | 1.714E-32 | 12.94   | 8       |
| 05:38 | 13.59   | 1.714E-32 | 11.89   | 4       |
| 05:43 | 13.60   | 1.698E-32 | 10.84   | 1       |
| 05:48 | 13.59   | 1.714E-32 | 09.78   | 8       |
| 05:53 | 13.53   | 1.811E-32 | 08.73   | 6       |
| 05:58 | 13.36   | 2.118E-32 | 07.68   | 5       |
| 06:03 | 12.96   | 3.062E-32 | -       | -       |
The relationship between the values calibrated of sky brightness (nL) versus sun's altitude (degree) at sunrise and sunset (moonless/full moon) will be presented in Figures 5 to 8.

| Time  | Sky Brightness | Calibrated (nL) | Sun's Altitude (degree) |
|-------|----------------|-----------------|-------------------------|
| 06:08:54 | 12.20          | 6.166E-32       | 0.63                    |
| 06:13:54 | 11.19          | 1.563E-31       | 0.58                    |
| 06:18:54 | 10.04          | 4.508E-31       | 0.48                    |
| 06:23:54 | 08.99          | 1.186E-30       | 0.44                    |
| 06:28:54 | 08.12          | 2.642E-30       | 0.39                    |
| 06:33:54 | 07.41          | 5.082E-30       | 0.35                    |

**Figure 5.** Sky brightness calibrated as a function of sun's altitude position on 27 December 2019 in Baghdad, Iraq, at sunrise and moonless phase.
Figure 6. Sky brightness calibrated as a function of sun's altitude position on 27 December 2019 in Baghdad, Iraq, at sunset and moonless phase.

Figure 7. Sky brightness calibrated as a function of sun's altitude position on 10 January 2020 in Baghdad, Iraq, at sunrise and full moon phase.

Figure 8. Sky brightness calibrated as a function of sun's altitude position on 10 January 2020 in Baghdad, Iraq, at sunset and full moon phase.
The important results are derived from previous figures was summarized in Table 3.

| Time of Observation | Moon's Phase | Sky Brightness (magnitude/arcsecond²) | Sun's Altitude (degree) |
|---------------------|--------------|---------------------------------------|------------------------|
| Sunrise             | Moonless     | 13.60±0.26                            | -9.79±0.12             |
|                     | Full Moon    | 12.75±0.25                            | -8.87±0.11             |
| Sunset              | Moonless     | 17.44±0.26                            | -10.66±0.12            |
|                     | Full Moon    | 15.69±0.25                            | 10.25±0.11             |

In this paper, the sky brightness level was studied and the influence of both the sun and the moon on it. The analyses of the values of sky brightness magnitude were correlated with sun's depression angle. Results showed that the sky brightness contrast is different from sunrise to sunset. The findings also showed that the observational values seem higher than the expected values indicating that an atmospheric and local condition affected the reading.

4. Discussion
The research was focused into the study of the influence of the lunar phase to the sky brightness contrast during sunrise and sunset. The data collected has represented the experimental values of sky brightness level variations. The data of sky brightness level was reflected the changes of the sky brightness magnitude as the time differences. This time are related to the sun height below (or above) the horizon. The magnitudes of sky brightness were affected by light pollution (artificial light), direct or scattered light, natural airglow, and zodiacal light. On the other hand, the lunar illumination has been studied based on the contrast of sky brightness backgrounds. By looking onto contrast model that relates directly to how the human eye perceives a bright object versus the background.

5. Conclusion and Recommendation
The study showed a correlation between the lunar phase and weather condition with the magnitude of sky brightness. Besides that, it is also showed a relationship between the sky brightness levels versus the sun's altitude angle. The results were indicated that the sky brightness value in Baghdad at the full moon phase is lower than the sky brightness value at the moonless phase due to the logarithmic scale. Therefore, brightness contrast of the sky was affected by moon's phase and atmospheric conditions. Last but not least, future researches should be proposed to study effects the properties of atmospheric on the brightness of the night sky.

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