Effect of the total lunar eclipse of 28 July 2018 on the night sky brightness at the Observatorium Ilmu Falak Universitas Muhammadiyah Sumatera Utara

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Abstract. The measurement of the Night Sky Brightness (NSB) has been done at the Observatorium Ilmu Falak Universitas Muhammadiyah Sumatera Utara (OIF UMSU) during the total lunar eclipse on 28 July 2018. NSB was measured using three Sky Quality Meters (SQMs). We were directing those SQMs to the eastern horizon, zenith, and the western horizon with a resolution of 2 seconds. The results showed that zenith direction SQM data had a change in NSB due to the lunar eclipse. Before the eclipse, the NSB was 14.78 mpsas, and the NSB during the total Moon phase was 18.03 mpsas. While the SQM data in the direction of the eastern and the western horizons are showing insignificant changes, those were 15.58 mpsas and 15.15 mpsas, respectively. These are because fog and light pollution originating from the city center of Medan are heavily influencing the area in the direction of the eastern and western horizons.

Keywords: lunar eclipse, sky quality meter, light pollution.

1. Introduction
A lunar eclipse passed Indonesia on 28 July 2018. This eclipse has the longest duration of 6 hours 13 minutes 48 seconds in the past 100 years. A lunar eclipse occurs when the Moon passes through the shadow of the Earth. The shadow produced by the Earth forms two cone-shaped components. They are the shadow of the penumbra and umbra. The shadow of the penumbra blocks part of the sunlight while the umbra shadow blocks all of the sunlight. Lunar eclipses always occur during full moons with longer duration than solar eclipses [1].

The total lunar eclipse occurs in six phases. They are the phase when the Moon enters the shadow of the Earth’s penumbra (P1), the Moon enters the umbra shadow of the Earth (U1), the beginning of total eclipse (U2), the end of total eclipse (U3), the Moon exits the shadow of the Earth’s umbra (U4), and the Moon comes out of the shadow of the Earth’s penumbra (P4) which indicates the eclipse has ended [2]. Eclipse phases are essential to measuring the characteristics of the atmosphere by looking at the color and brightness of the Moon [3]. The number of particles in the atmosphere is one of the factors that affect the sky brightness. These particles will give the effect of scattering and absorption [4]. Another factor that can affect sky brightness is the Moon phase [5]. The sky will look the brightest during the full moon because the Moon’s appearance is maximal so that the light emitted by the Moon becomes brighter.
Measuring the sky brightness is very important to determine the level of light pollution in a particular site [6]. Light pollution has become a problem throughout the world because it gradually reduces the chance to see stars also reduces the number of light-sensitive species [7] [8]. Moreover, changes in sky brightness can also be used to measure the beginning and the end of the astronomical dusk. Early evening astronomy was the right time for observers to begin observing the night sky because there was no influence from the scattering of sunlight in the sky. For Muslims, studying sky brightness will lead to the determination of prayer times, although they can be simulated using Tellurium [9] [10] today. To measure sky brightness, we can use the Sky Quality Meter (SQM) photometers. SQM is a device that can be used to measure the intensity of the night sky with pocket size and low price, as shown in Figure 1.

The device allows the general public to measure the quality of the night sky anywhere anytime [11]. SQM measures the sky brightness in the unit of magnitudes per square arc seconds (mpas). SQM can also be used to determine light pollution in a place and the initial interaction of a solar eclipse [4]. The SQM spectral response is in a reasonably wide range, namely the visual range 400–650 nm for transmission 0.5 with a peak transmission of around 540 nm. Thus the SQM spectral range corresponds to the spectral sensitivity of the human eye. The light physical dimensions and ease of high-resolution data acquisition open up opportunities for broader use of SQM with high mobility to determine the time of Subuh prayer [12].

Various factors can affect the night sky brightness. Factors that affect SQM in the light collection are human-made light pollution (street lights, office buildings, etc.), moonlight, aurora, airglow, the light of the Milky Way galaxy, humidity, volcano eruption, and zodiacal light [13]. Taking a lot of data will be very useful in overruling the moment during the data retrieval process. SQM collects and records photons in at least one second, and the results obtained are based on the light that accumulates during that time. This study aims to determine the effect of a total lunar eclipse of 28 July 2018 on night sky brightness at Observatorium Ilmu Falak Universitas Muhammadiyah Sumatera Utara (OIF UMSU).

2. Methods

Sky brightness is measured using three SQMs, which are installed and directed to three different directions, namely zenith, eastern horizon, and western horizon. SQM is connected to a computer using a USB cable. The frequency of SQM data retrieval is determined every 2 seconds. SQM output is in the form of text data and processed using Microsoft Excel software. SQM has an effective angle of 20 degrees while the Moon has a diameter of 0.5 degrees. Data retrieval with SQM was conducted at OIF UMSU (3° 34' 55.06'' N, 98° 43' 17.09'' E), on the 7th floor of the UMSU postgraduate campus.

3. Result and discussion

The phases of the total lunar eclipse on 28 July 2018 can be seen in figure 2. The lunar eclipse started when the Moon entered the shadow of the Earth’s penumbra (P1) at 17:14:49 universal time (UT) or 00:14:49 local time (WIB), and the lunar eclipse ends at 06:28:37 WIB. The red circle is the shadow of
the Earth’s umbra, while the gray circle is a shadow of the Earth’s penumbra. The total lunar eclipse phase occurs when the entire surface of the Moon enters the shadow of the Earth’s umbra.

**Figure 2.** Phases of 28 July 2018 total lunar eclipse (Espenak, 2018).

Figure 3 shows the phases of the lunar eclipse obtained from observations in OIF UMSU. The lunar eclipse phase is observed only until the total lunar eclipse phase. After that, thick clouds cover the visible surface of the Moon so that the remaining phase is no longer viewable. The image was captured by using a camera connected to a telescope. It can be seen from figure 3 that the shadow of the Earth begins to enter the surface of the moon. The part of the surface of the Moon becomes dark. The reddish color is because, during the lunar eclipse, there is a total amount of sunlight that passes through the atmosphere of the Earth and towards the Moon.

**Figure 3.** The lunar eclipse phases which were seen from OIF UMSU (using Nikon D7100 DSLR camera and William Optic GT102).

Figure 4 shows the sky brightness of three SQMs installed in different directions during the total lunar eclipse on 28 July 2018. The horizontal axis shows the time at the observation location (WIB), and the vertical axis shows the sky brightness level. Red, blue, and green lines denote data from SQM directed towards the eastern horizon, the western horizon, and the zenith, respectively. Six vertical lines indicate the time of the eclipse phases. The black vertical lines show the time when the phases started, while the orange vertical lines show the time when the phases completed. The dashed vertical lines indicate the time during the penumbral phases P1 and P4; the dotted vertical lines indicate the time of the umbral phases U1 and U4; while the thick lines indicate the time at the beginning (U2) and the end (U3) of the total eclipse phase. The condition of the sky during the data collection is dominated by the number of clouds sometimes even to cover the sky. The green line shows the change in value when the eclipse occurs, but the blue and the red lines show insignificant changes in value.
Figure 4. Graph of sky brightness from three SQMs with different angles.

The value of sky brightness recorded by SQM placed in the direction of the zenith denotes by the green line, shows a value of 14.78 mpsas when the Moon enters the shadow of the Earth’s penumbra (P1), but this value had declined to 14.49 mpsas at 12:22:11 WIB. After entering the eclipse phase, the magnitude of sky brightness is higher because the greater the value of sky brightness is obtained, the darker the sky, and vice versa. The darker sky could be due to the influence of clouds in the sky. When the Moon enters the umbra shadow of the Earth (U1), the value obtained is 16.17 mpsas. During this phase, it is also still colored by many clouds that pass. The clear sky is free of clouds before the Moon entering the total eclipse phase. The total lunar eclipse phase starts (U2) at 02:30:15 WIB. In this phase, the value obtained is 18.03 mpsas. The clouds began to cover the sky when the total eclipse phase was in progress, making the value obtained became smaller before the total lunar eclipse phase ended.

The sky brightness value obtained by SQM directed to the zenith at U1 is 16.17 mpsas, while that at U4 is 16.68 mpsas. During the U1 phase, there are many clouds in the sky, and the Moon's altitude is 66 degrees. Whereas during the U4 phase, the sky is clear again, but the Moon has an altitude of 16 degrees. The Moon is also invisible because clouds cover it in the western horizon sky. The cloud coverage causes the sky brightness value at U1 is smaller than that at U4.

SQMs which are directed to the eastern and western horizons does not show much change in value when the lunar eclipse takes place. The slight variation is because fog and clouds cover the sky on the eastern and western horizons. The observation site is close to the center of the city so the resulting light pollution is high. With the effective angle of the SQM of 20 degrees, when the SQMs are directed to the eastern and western horizons, they also directly recorded the light from the houses and buildings. The light pollution results in the unchanging value of the sky brightness during a total lunar eclipse.

The sky brightness recorded by SQM directed to the western horizon denotes by the blue line shows values of 14.95 mpsas at P1 and 15.15 mpsas when entering the eclipse phase. While that directed to the eastern horizon or the red line shows values of 15.40 mpsas at P1 and 15.58 mpsas when entering the lunar eclipse phase. Before 06:00:00 WIB, the three lines significantly decreased. The decrement happens because the sunlight begins to illuminate the Earth's atmosphere, which signifies dawn has risen. The value obtained continues to decrease until the lowest magnitude limit of the SQM.
Figure 5. The sky brightness value from three SQMs during the total lunar eclipse phase.

Figure 5 is a magnification of figure 4 that shows the sky brightness value of the three SQMs during the total lunar eclipse phase. When approaching the total lunar eclipse phase, only the sky brightness value of the SQM directed to the zenith experienced a temporary. When the total lunar eclipse phase, the value of sky brightness obtained from SQM directed towards the zenith slowly decreases due to clouds that cover the appearance of the Moon until the total lunar eclipse phase ends.

Figure 6. Light pollution map at OIF UMSU (https://www.lightpollutionmap.info).

Figure 6 shows a map of light pollution in the city of Medan. The color on the map shows the level of light pollution that exists. The brighter colors shown on the map indicate the greater the light pollution in the area. The darker colors shown on the map indicate that the light pollution in the location is getting smaller. The red pin on the map is the location of the observation, OIF UMSU. The observation location is in a white area, which indicates that the site of data collection has very high light pollution. The light pollution affects the value obtained from observations.
4. Conclusions
Based on the results obtained, it can be concluded that:
1. The total lunar eclipse on 28 July 2018 affects the sky brightness in OIF UMSU.
2. The maximum value obtained is 18.07 mpsas from SQM, which is mounted towards the zenith.
3. For locations around the city center, the installation of SQMs directed to the eastern and western horizons is not suitable because they will also record the light from buildings around the location.

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