Measurement of The Night Sky Brightness in e-Maya Observatory

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Abstract. One of the ideal criteria for an observatory is the location that is related to its influence on the condition of the night sky. The observatory area is a light pollution-free area, far from the city or urban center. This is intended to get a dark night environment so the observations can be done well. The e-Maya Observatory is one of the observatories in Indonesia that located in Subang, West Java. Established in 2013, the observatory's work is relatively new in Astronomy field in Indonesia. This observatory was built in the area of Astha Hannas Subang High School which is about 18 km to the north from the center of Subang city. To find out the quality of the night sky and how big the impact of city lighting or the level of light pollution in the e-Maya Observatory area, it is necessary to measure the brightness of the night sky. Measurement of the night sky brightness used a simple sky brightness photometer, Sky Quality Meter (SQM), there are two SQM types used, SQM LU and SQM LU-DL. SQM measures the brightness value of the night sky in magnitude per squared arcseconds (mag/arc sec²) all night on August 11-14, 2018 towards the east and west horizons with the slope angle of 30° (z = 60°) and pointed to zenith (z = 0°).

1. Introduction
The observatory as a place for observing and making research on celestial bodies has an important role in the advancement of astronomical knowledge [1]. The construction of an observatory in a school environment has a motivation as a center of learning science, especially astronomy, for young students. One of the school observatories is e-Maya Observatory at Astha Hannas Subang High School, West Java, Indonesia, 6° 24' 15" S 107° 47' 39" E. It was built in 2013, so the observatory's work is relatively new in the Indonesian astronomy field. The observatory building is closely related to the dark night environment conditions and the quality of the night sky which is good for observing so it can produces good data. According to Tulloch [2] an observatory must have some ideal criteria such as being located in the countryside far from the city center or urban area, a light pollution-free area, no interference from street lighting and traffic lights, at higher place than the surrounding area by considering the selection of locations that avoid strong winds and atmospheric seeing and yearly large percentage of clear skies or free of clouds. Based on the ideal criteria of the observatory, one of the basic things needed by an observer is the clear condition, unpolluted night sky [3]. So it is necessary to have a brightness measurement of the night sky to find out and monitor the quality of the night sky and how much the impact of city lighting or the level of light pollution in the e-Maya Observatory area.
2. Method
The measurement of the night sky brightness has been done in e-Maya Observatory that a school observatory. Built in the area of Astha Hannas Subang High School which is about 250 m from the main entrance and 18 km to the north from Subang downtown. The observatory is above the main building, the Bhaktinagara Graha building at 220 m above sea level. The instrument used is a simple sky brightness photometer, Sky Quality Meter (SQM). There are two SQM types used, SQM LU (with Lens-USB, the type of SQM that has a lens with a USB connection, connected to the computer during data retrieval) [4] and SQM LU-DL (with Lens-USB-Data Logger, upgrade from LU type, data retrieval is automatically recorded in internal recording, using a battery without connected to a computer) [5] which is directed in two different directions.

Both are mounted on a tripod as a holder that is directed to the zenith (z = 0°) (SQM LU-DL) and towards the west and east horizons (SQM LU) at the location of sunrise and sunset with the SQM slope angle of 30° (z = 60°, SQM coverage area ~20° [6]). The installation of SQM LU towards the west horizon when the sun sets until midnight (17:30-23:59 UTC+7:00), then towards the east horizon at midnight until the sun rises (0:00-6:00 UTC+7:00). Tripod has a protractor to measure the accuracy of the tilt angle. Two SQMs installed in different directions to detect the differences in brightness profiles based on differences in atmospheric thickness. SQM measures the brightness value of the night sky (how much light is captured by the sensor) in units of magnitude per squared arc seconds (mag/arc sec²), which is a logarithmic scale decreasing with increasing brightness (the higher magnitude, the darker sky) [7]. Data retrieval is carried out for 3 nights on August 11-14, 2018, with time interval every second for SQM LU and every three seconds for SQM LU-DL to get a tight data and minimize errors. The timing of data retrieval considering the Moon phase, when the new Moon towards waxing crescent phase because the Moon's light can affect the results of the brightness measurement of the night sky.

3. Result
The e-Maya Observatory as a school observatory, is in the Astha Hannas Subang High School area, located on the edge of Subang city which is still a rice fields environment. Overall, the school environment is a dark area, just a little artificial light. Precisely, the closest artificial light source to the observatory is the spotlight that leads to the main building, the Bhaktinagara Graha building. The spotlight does not point directly to the observatory but the spread of light disturb the observations, especially in the northern sky of the observatory. With a poor design, the spotlight made the observatory night sky worse and the environment will polluted by undesired light [8]. The light scattering that filled the sky was called sky glow, the one of main types of light pollution [9]. The measurement of the night sky brightness consciously chosen during the new Moon phase, so the night sky is not disturbed by the Moon's light.

Figure 1 shows the night sky brightness data of the e-Maya Observatory for every second taken from 17:30 until 6:00 (UTC+7:00) during 3 nights on August 11-14, 2018 using SQM LU, towards the west and east horizons with the slope angle of 30° (z = 60°) and the data for every three seconds using SQM LU-DL pointed to zenith (z = 0°). Table 1 shows SQM reading for maximum and average sky brightness, the night sky/weather condition and moon appearance for each night. The maximum sky brightness is the highest value during data retrieval start from evening until morning twilight. While the average sky brightness is mean value throughout the night (after dusk and before dawn, from 19:00 until 5:00 (UTC+7:00)). The night sky condition is visual observation during data retrieval.
Figure 1. Night sky brightness observed in e-Maya Observatory. (above) the data for every second using SQM LU towards the west and east ($z = 60^\circ$), (below) the data for every three seconds using SQM LU-DL pointed to zenith ($z = 0^\circ$).

Table 1. Maximum and average sky brightness, night sky/weather condition and moon appearance for each night

| Date and Time (UTC+7:00) | Maximum Sky Brightness (mag/arc sec²) | Average Sky Brightness All Night (mag/arc sec²) | Night Sky/Weather Condition | Moon Appearance (Phase; Rise; Set (UTC+7:00)) |
|--------------------------|----------------------------------------|-----------------------------------------------|-----------------------------|-----------------------------------------------|
|                          | $z = 60^\circ$ | $z = 0^\circ$ | $z = 60^\circ$ | $z = 0^\circ$                  |
| Aug 11-12, 2018 17:30-6:00 | 20.38 | 20.03 | 19.74 | 19.4 | Partly cloudy | New Moon; 5:39; 17:50 |
| Aug 12-13, 2018 17:30-6:00 | 19.15 | 19.68 | 18.44 | 19.25 | Cloudy | Waxing crescent; 6:36; 18:50 |
| Aug 13-14, 2018 17:30-6:00 | 19.36 | 19.85 | 19.08 | 19.4 | Partly cloudy | Waxing crescent; 7:31; 19:48 |
From Table 1, it is known that the maximum value of the night sky brightness using SQM LU (z = 60°) is 20.38 mag/arc sec² with the average sky brightness 19.74 mag/arc sec². Using SQM LU-DL (z = 0°) the maximum value is 20.03 mag/arc sec² with the average sky brightness 19.4 mag/arc sec². While the lowest value using SQM LU is 19.15 mag/arc sec² with the average 18.44 mag/arc sec² and SQM LU-DL is 19.68 mag/arc sec² with the average 19.25 mag/arc sec². Evenly SQM LU shows a lower value than SQM LU-DL. It proves that the differences in sky brightness is influenced by differences in atmospheric thickness. Especially at cloudy night on August 12-13, 2018, the distribution of clouds is concentrated in the horizon than the zenith. While the difference in value every night is affected by weather conditions at night during data retrieval. The clouds contributes to the spread of artificial light throughout the sky, so that the sky is getting brighter.

4. Discussion and Conclusion
The International Dark Sky Places’ program guidelines [10] explains that there are three levels of sky brightness; gold (>21.75 mag/arc sec²), silver (21.74-21.00 mag/arc sec²) and bronze (20.99-20.00 mag/arc sec²). Beside that, the night sky brightness level can stated in Bortle Dark-Sky Scale. It measures the night sky brightness with scale ranges from class 1 through 9, from the darkest until inner-city typical skies [10]. Based on this level, the night sky brightness of the e-Maya Observatory is included in the bronze level or according to Bortle Scale is in the class 5-6. Bronze level has a visual limiting magnitude 5.0 to 5.9 under clear skies and good seeing conditions. As a comparison, measured on July 2015, the night sky brightness at Bosscha Observatory as a national observatory is ~21 mag/arc sec² (silver level, class 3-5). While the night sky brightness measurement in Timau, Amfoang, Kupang on May 2013, as the location of the new National Observatory that currently under construction is 22.5 mag/arc sec² (gold level, class 1-3) [11]. The measurement of the night sky brightness in e-Maya Observatory was influenced by cloudy sky conditions. So that it should be in a clear sky condition from clouds can become darker. Therefore, the measurement of the night sky brightness throughout the year needs to be done to produce better data. It can also be known the best time for astronomical observations throughout the year.

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