The sky brightness measurement during the 2016 solar eclipse in Ternate

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The sky brightness measurement during the 2016 solar eclipse in Ternate

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Abstract. Obscuration of the Sun by the Moon during total solar eclipse generates the changing of the sky brightness. Sky Quality Meter (SQM) was employed to measure the sky brightness during the 2016 total solar eclipse. The sky was still bright at the first contact time. It is shown by the SQM value of zero. Approaching the second contact time, the SQM value is rising up started at the value of 5.92 mpsas. The curvature profile of the SQM measurementvalue is similar to the curvature profile of the SQM measurement at the dawn and dusk. However, the flatness part of the curvature is much shorter than night time value of SQM. The maximum of SQM measurement value is lower than the SQM measurement value during the night in Ternate. It is 12.47 mpsas and happened at the maximum phase of the eclipse. It was confirmed by the fact that at the time of totality, the sky close to the horizon was still bright. There is a discrepancy between the predicted and actual second and third contact and maximum eclipse time. By assigning the maximum of SQM measurement value as the reference value of maximum eclipse time, the actual second and third time can be calculated. The shape of curvature between the actual second and third contact time is symmetry.

1. Introduction

The total solar eclipse path of March 9^{th}, 2016 was stretches across Indonesia. The total solar eclipse occured since early morning in the western part of Indonesia until mid-day in the eastern part of Indonesia. Hence, the sun altitude vary across Indonesia. The sky brightness depends on the sun altitude. During the night, when the sun altitude is negative, the sky will be dark. The sun disk is covered by the moon disk during the totality. Hence, the sun rays is blocked. The sky begins to darken to be a night-like sky.

Number of research activites has been done to observe the solar eclipse phenomenon. The sky brightness during the total solar eclipse has been measured on number of occasion such as 1954 Sweden Eclipse [1], 1970 African Eclipse [2] and 1973 American Eclipse [3]. The radio telescope was employed on the 1954 Sweden Eclipse. The photometer was used on the 1970 and 1973 eclipse. The sky brightness measured on the zenith direction that was measured during the 1970 Eclipse showed decreasing value up to four order of magnitude compared to normal day sky. The sun altitude was 46° from the horizon. Similar results was also obtained from the measurement of 1973 Eclipse with the sun altitude was 37° from the horizon.

Another factor contributing to the sky brightness is the number of particle in the atmosphere. The particles will give the effect of scattering and absorption. The model has also been calculated to investigate the scattering contribution to the sky radiance during the total solar eclipse [4]. Hence, it is important to measure the sky brightness to understand characteristics of the atmosphere at the time of eclipse. This research is intended to measure the sky brightness changes during totality.

2. Instrumentation

The sky brightness measurement has been done using Unihedron Sky Quality Meter (SQM). It is inexpensive and compact size sky brightness photometer. It provides the value of sky brightness. It only measures the visible light and blocks the infrared light.The value is expressed in the unit of magnitude per square arc second (mpsas) on a logarithmic scale. The mpsas means the brightness is spread over an area of squared arc second. The higher value of SQM measurement means the darker sky. Since, it is related to the apparent magnitude of the star, higher value of apparent magnitude dimmer the star.

The SQM has two types. They are SQM and SQM-L. The SQM-L covers the 20° angular region of sky [5]. The SQM was installed to the zenith direction. It is connected to the computer via USB cable since it is SQM-LU. The computer is AXIOO with Windows 8 operating system, Intel(R) Celeron(R) CPU N2940 1.83 GHz processor and 2.00 GB RAM. For the rest of the article, the SQM-L is written as SQM only. On this research, the SQM took the data every 1 second.

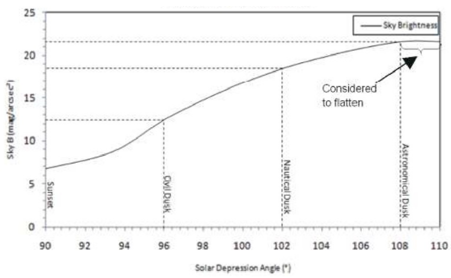

Figure 1. The sky brightness as a function solar depression angle [6]

The SQM is usually employed to measure the night sky brigthness quality. Since the sky brightness depends on sun altitude, the SQM is able to measure the changes of sky brightness in function of time. As the time changes, the sun altitude or the solar depression angle changes as shown in figure 1 [6]. The change can be used to perform analysis of twilight time.

To provide additional data about the sky condition, two cameras were employed during the totality. The first camera is digital camera of CANON EOS 600D. The second one is the ASUS Zenfone 5 camera smartphone 8 Megapixels.

3. Observations

The observation has been done in the terrace of Masjid Al Munawar, Ternate, Indonesia. The latitude is 0.7898° North and longitude is 127.3907°. It is located at 2 meters above sea level. The location position data is obtained using google maps. The observation location is in the totality path. However, it is about 42 kilometers north of the center line of totality path.

There were 2 times of measurement. The first one was measuring the sky brightness before the dawn. The second one was running the SQM during the eclipse. The first measurement can be used to compare the sky brightness during the totality to the night sky brightness. The time of measurement has been synchronized with the offiicial time of BMKG (Indonesian Agency of Meteorological, Climatological, and Geophysical). The Local Time (LT) is Universal Time (UT) + 9 hours. The first, second, third and fourth contact was occured at 08:36:04.8 LT, 09:51:41.9

LT, 09:54:22:0 LT and 11:20:53.0 LT respectively according to the NASA prediction data. The sun altitude also is obtained from NASA calculation. The sun altitude of maximum eclipse was 47.7° at 09:53:01.6 LT. It is similar to the 1970 Elipse sun altitude measurement. The predicted duration of totality was 2 minutes and 40 seconds.

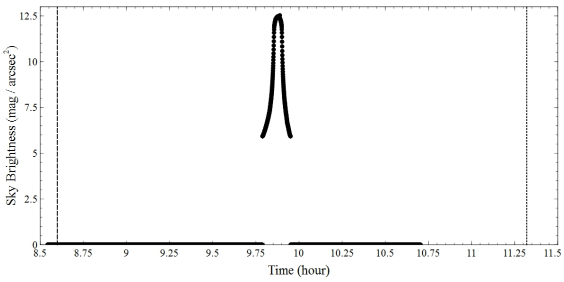

Figure 2. The SQM measurement during the solar eclipse. The vertical dashed line on the left side marked the first contact and the vertical dot line on the right side marked the fourth contact of the solar eclipse.

4. Result and analysis

The SQM measurement during the solar eclipse is shown in figure 2. The predicted first contact time is shown by the vertical dased line on the left side. The sky was still bright, hence the SQM reading is zero. The vertical dot line on the right side give the information the predicted time of the fourth contact. However, the observation has been stopped before the fourth contact. By extrapolation, the SQM reading is zero at that time. It means, the sky is bright like the normal day sky.

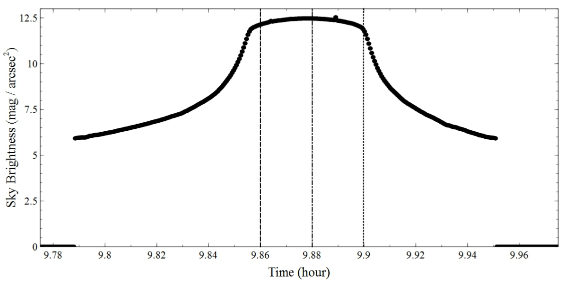

Figure 3. The SQM measurement during the solar eclipse. The vertical dashed line on the left side marked the predicted second contact time, the vertical dashed-dot line marked the predicted maximum eclipse time and the vertical dot line on the right side marked the predicted fourth contact time of the solar eclipse.

To investigate the second and the third contact and maximum eclipse, figure 2 is zoomed in as shown in figure 3. The vertical dashed line on the left is the predicted second contact time. The vertical dased-dot line in the middle is the predicted maximum eclipse time. The vertical dot line in the right side is the predicted third contact time. The predicted maximum eclipse time was occured after the SQM measurement reach the maximum value. The maximum value is 12.47 mpsas at 9:52:41 LT. Ignoring the spike that occurs in the right due to electronical signal transmission. There is a discrepancy between the predicted and actual time. The position of the predicted second and third contact time are asymmetry.

Hence, the actual time is used as reference to calculate the actual second and third contact time. The predicted duration is also used to generate the results. Hence, the calculated second and third contact time are 9:51:21 LT and 9:54:1 LT, respectively. Those times correspond to the SQM value of 11.75 mpsas and 11.76 mpsas, respectively. Based on this calculation, by keeping fix duration of totality, the SQM value of the second and third contact are similar.

The maximum SQM value is compared to the SQM measurement before dawn on the same day. Based on the profile as shown in figure 1, the maximum and flat SQM value is 19.6 mpsas. Hence, the difference between the eclipse sky brightness and normal night sky brightness is 7.13 mpsas. The sky brightness during totality was not completely dark. The sky close to the horizon was still bright as shown in figure 4. It was similar to the condition at the dawn or dusk.

Figure 4. The sky brightness condition during the totality as captured by digital camera. The sun at the totality phase can be seen on the camera display

The SQM measurement curve is asymmetry. This is due to the apperance of cloud. The cloudy condition occured before and after the totality. At the time of the totality, the sky was clear. The SQM mesaurement value jumps from zero to 5.92 mpsas due to sensitivy threshold of instrument. However, the curvature of SQM measurement value is similar to the profile as shown in figure 1. The maximum of SQM measurement value and and its curvature profile can be used for analysing particle scattering and absorption in the atmosphere that influence the sky brightness.

5. Conclusion

The sky brightness during the total solar eclipse has been done in Ternate using SQM-LU. There is discrepancy between the predicted and actual contact time. The maximum of SQM measurement value is lower than the normal night sky brightness. These phenomenon can be explained by off-center line of totality path and particle scattering and absorption in the atmosphere. The curvature profile is similar to the curvature profile of dawn and dusk.

6. Acknowledgment

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