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Assessment of Night Sky Quality in Ganten Village, Kerjo District, Karanganyar: A Prospective Evaluation for the Establishment of the Falak Observatory

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Abstract

The establishment of an astronomical observatory requires a thorough evaluation of meteorological parameters and Night Sky Brightness Levels (NSBL). This research focuses on assessing the potential of Karanganyar as a site for astronomical education and new moon observations. To determine the NSBL in Karanganyar, satellite imagery was used, indicating favourable conditions. However, NSBL can be affected by light pollution and moon phases in specific locations. To complement the satellite data, additional measurements were taken using a Sky Quality Meter (SQM). The SQM values were processed using probability distribution analysis and showed a highest probability NSBL value of 17.22 mag/arsec2, while the maximum NSBL value reached 20.99 mag/arsec2. The NSBL derived from satellite data was 21.47 mag/arsec2. Our study shows that Karanganyar has predominantly high NSBL, suggesting low light pollution and excellent sky clarity in the region.

Kata kunci : Probability Distribution, Sky Brightness Level, Light Pollution

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A. Introduction

Light pollution refers to the presence of artificial and natural light that causes discomfort and obscures celestial bodies such as stars[1]. Sources of artificial light pollution include domestic and street lighting, night markets and park lighting, while natural light pollution occurs during full moons and other celestial events. The brightness of the night sky is influenced by factors such as auroras, stars, man-made lighting and the sun's interaction with the atmosphere[23].

In terms of measurement techniques, the use of digital cameras calibrated with fisheye lenses is recommended, as it balances ease of use with the information obtained. However, single-band instruments can introduce errors related to long-term variations in sky brightness[4].

The Sky Quality Meter (SQM) is aimed at the zenith to measure light pollution levels. The study reported Night Sky Brightness Level (NSBL) values of 15.5 mag/arcsec2, 14.61 mag/arcsec2, and 15.02 mag/arcsec2 on 23, 24, and 25 March 2018, respectively, indicating high levels of light pollution in Yogyakarta. The study recommends reducing light pollution by switching off unnecessary lights.[5].

Light pollution is a major challenge for astronomers as it makes it harder to observe stars by dimming their light. Higher sky magnitudes indicate darker skies and less light pollution. To mitigate light pollution, outdoor luminaires and street lights can be shielded to minimise upward light emission.

Given the importance of NSBL for astronomical observations, it is crucial to conduct NSBL studies in different regions, especially in potential observatory areas. Measurements of sky brightness in places such as Bosscha Observatory, Cimahi, Yogyakarta and Kupang show that Kupang has the highest sky brightness at night, while Cimahi has the highest level of air and light pollution, both of which significantly affect sky brightness.[6].

[1]Longcore T. Rich C. *Ecological Light Pollution* (America : The Ecological,2004) h.191-198.

[2] Cinzano P. *Night Sky Photometry with Sky Quality Meter* (intitusi di Science Tecnologia dell' Inquaninamento Lumins, 2005), h. 1-13

[3] Miller S.D. Mills W.S. Elvidge S.P. Lee C.D. SolbringnT.F. *Illuminating the Capabilities of The Suomi National Polar-Orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIRS) day/night band remoting Sensing*, (2013)h.6717-6766,v.5

[4] Hanel A. Posch T, J Ribas.S Aub. Duriscoe M. Jechow A. *Mengukur Kecerahan Langit Malam : Metode dan Tantangan.*(Jurnal Spektroskopi Kuantitatif dan Transfer Radioaktif, 2017) , h.1-44

[5] Sukma M. Pramudya Y. Muchlas . Okimustava. *Night Sky Brightness Measurement during the March 2018 Earth Hour in Yogyakarta* (Journal of Physics: Conference Series vol.1231, 2019), h.1-5

[6] Herdiwijaya D. *Measurement of Night Sky Brightness towards Zenith for Determination of Fajr*

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The first step in addressing light pollution is to improve the quality of lighting. Steps to improve lighting quality include maximising the acquisition of visual information by optimising human visual capabilities. In addition, improving lighting quality minimises adverse effects such as energy wastage and glare for people[7].

Researchers use the Night Sky Brightness Level (NSBL), expressed in magnitudes per square arc second, to quantify sky conditions. The NSBL can be measured using the Sky Quality Meter (SQM) tool, as shown in Figure 1. This user-friendly tool allows the general public to assess the quality of the night sky at different locations and times. Data processing of SQM measurements is straightforward, using Microsoft Excel software and mathematical functions such as moving averages to determine the NSBL and its rate of change[8].

Figure 1. SQM device

In early dawn observation studies, SQM was used to find an ideal night sky quality limit of 20.35 mag/arcsec[29], indicating favourable conditions. In addition, SQM has been used to investigate the position of intercession and dawn for determining the height of the sun during Isha and Subuh prayers[10].

When the SQM was directed towards the eastern horizon, the sky brightness values obtained were generally lower than those obtained in other directions. Although the readings appeared more consistent, the maximum sky brightness value obtained was lower than when the SQM was directed towards the zenith. This discrepancy can be attributed to the greater presence and stability of clouds in the 450 direction, resulting in higher sky brightness values at the zenith[11].

Time. (continued SKF, 2016) pp. 95-102

[7] Walker CE. SM pump. Sparksa RT. Doctor E. *Learning Lighting Techniques using Light Pollution Education Kit*. (SPIE Optical Engineering+Applications, 2010) v.7783, p.1-11

[8] Raisal AY. Pramudya Y. Okimustava, Muchlas. 'Utilization of the Moving Average Method in Determining the Beginning of Fajr Prayer Time using Sky Quality Meter (SQM)', Al-Marshad: Journal of Islamic Astronomy and Related Sciences, Vol.5 No.1(2019), pp. 1-13

[9] Damanhuri A, Solikin A. *Ideal Sky Quality Limits for Initial Observation locations Dawn time.* Al-Marshad: Journal of Islamic Astronomy and Related Sciences, Vol.8

[10] Ritonga M, *The problem of shafak and dawn in determining the time of isyak and dawn prayers.* . Al-Marshad: Journal of Islamic Astronomy and Related Sciences, Vol.7

[11] Rakhmadi A.J, SetiawanH.R, Raisal A.Y. *Measurement of Light Pollution Level and early dawn time at OIF UMSU using Sky Quality Meter.* Multi

AL-MARSHAD: JURNAL ASTRONOMI ISLAM DAN ILMU-ILMU BERKAITAN
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Research has highlighted the adverse effects of light pollution on human, environmental and animal health. Analysis of the different energy emissions of different types of lamps, particularly blue emissions, is crucial. Excessive exposure to blue light can affect night vision and health, highlighting the need to reduce the use of lamps that emit blue light[12]. Artificial light pollution at night leads to wasted energy, reduced visibility due to glare and the loss of a pristine starry sky[13]. In the case of Barus, for example, the use of lights led to a 3.3-fold increase in sky brightness. The research site also identified multiple light sources, such as fishing activities, feeding areas and human settlements, that contribute to potential light pollution[14]. The analysis of the NSBL measurement can be supported by macro Excel software[15].

Considering the significant effects of light pollution described above, it is evident that several areas still face significant light pollution problems. Therefore, it is crucial to conduct observations and research to assess the brightness profile of the night sky, particularly in Karanganyar. This initial study aims to assess the potential for educational and observational purposes in Karanganyar, contributing to a comprehensive understanding of the state of the sky in the region.

B. Research Methods

Data collection was done by observing sky conditions using SQM. This research is located at Jl.Waduk Gondang, Jenggrik Village, Ganten, Kerjo District, Karanganyar Regency, Central Java. The data collection position is at latitude -7o34'26.7" and longitude 111o4'38.1". The tools used during the research are laptop/notebook, SQM, connector cable to connect between SQM sensors and notebook. The software used is Microsoft Excel, Stellarium and Unihedron software. Paralon tubes along with caps and glass are used to protect the SQM from weather changes.

The research procedure involved the use of a protective setup for the Sky Quality Meter (SQM) as shown in Figure 2. A

Sciences Scientific Journal, Vol.12. No.2 (2020), p.58-65

[12] Falchi F, Cinzano P, Elvidge CD, *Limiting the impact of light pollution on human health, the environment and star visibility*. Journal of EnviromentalManagement, (2011),pp.1-9

[13] Luginbuhl CB, Walker CE, Wainscoat R J, *Lightting and astronomy*. American Institute of Physics, (2009), pp.32-27

[14] Firdaus M.D, Rakhmadi A.F,PutragaH, Hidayat M, Analysis of the *impact of artificial lamp light pollution on the brightness of the night sky using SKY QUALITY METER*, Elfalaky Journal : Journal of Falak Science (2022), v.6 no.2, p.197-206

[15] Ahyar M, Pramudya Y, Okimustava. Implementation of a virtual basic-based Sky Quality Meter data processing system for the analysis of changes in sky brightness (2020), p. 239-246

AL-MARSHAD: JURNAL ASTRONOMI ISLAM DAN ILMU-ILMU BERKAITAN
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cylindrical Paralon tube with dimensions of 26 cm in length and 9.5 cm in diameter was used. Within the tube, a centrally positioned glass hole of 3 cm diameter and 3 mm thickness was incorporated. This arrangement ensured the secure placement of the SQM within the Paralon tube, protecting it from rainwater and adverse weather conditions.

Figure 2. The housing of the SQM is made of tube.

Following the setup described above, the Sky Quality Meter (SQM) was connected to a netbook using an SQM cable, pointing towards the sky or zenith, as shown in Figure 3.

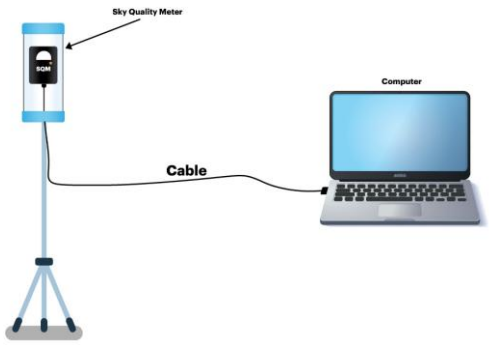

Figure 3. Installation of SQM and the connection to the computer

The zenith installation was chosen to minimise the influence of man-made light sources and ensure that the data collected would not be affected. In addition, this installation configuration ensured that the SQM was not obstructed by buildings or trees.

The SQM was operated using Unihedron Device Manager software which enabled continuous data logging at 1 minute intervals. The data collected was automatically stored on the netbook in .dat format. The data was then transferred to Microsoft Excel for further analysis, including the creation of NSBL graphs. In addition, data for different phases of the moon, including new moon, full moon, first quarter moon and last quarter moon phases were included in the analysis.

Data processing and analysis was carried out in Microsoft Excel, using optimisation techniques such as moving averages to assess changes in NSBL values over time. This comprehensive analysis helped to understand the variations in night sky brightness and their correlation with different lunar phases.

The first step is to calculate the probability value for each lunar phase, with x and y values.

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$$y_i = \frac{\sum k(x)_i}{n}$$

with

k = number of events per SQM value

n = amount of data per SQM data retrieval

y = number of SQM data values

x = SQM value

The total value for all y must be equal to 1 because it is the total probability. The second step is to find a comparison between the results of the NSBL in Karanganyar with the satellite data and to plot the relationship between NSBL and time.

C. Results and Discussion

1. Probability and Sky Brightness Profile

The research results include probability plots for different phases of the moon. Figure 4 shows the probability plot for the first quarter moon phase, which shows that the highest probability density for night sky brightness occurs at NSBL 18.42 mag/arcsec^2 with a chance of occurrence of 9%.

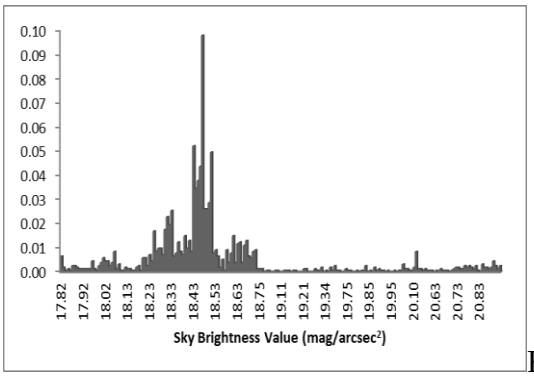

Figure 4. Probability Graph of the phases of the first quarter moon

Similarly, Figure 5 shows a probability plot for the new moon phase, where the highest probability is observed at a value of 17.22 mag/arcsec2 with a probability of 5%. These probability values and plots are remarkably similar due to the lack of visibility of the Moon or its position below the horizon during these phases.

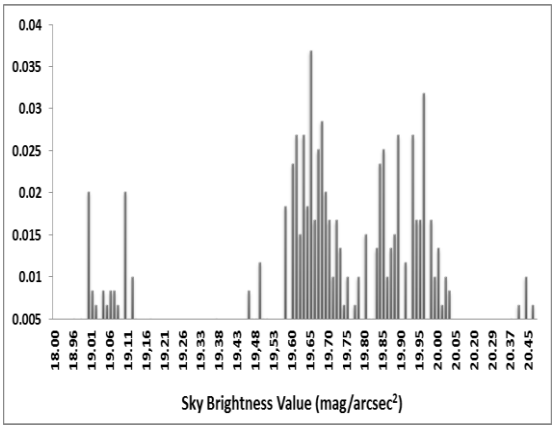

Figure 5. New moon phase graph of probability density function

Figure 6 shows the probability density of NSBL during the full moon phase. The highest probability value is 17.76 mag/arcsec^2 and the probability of occurrence is 5.9%.

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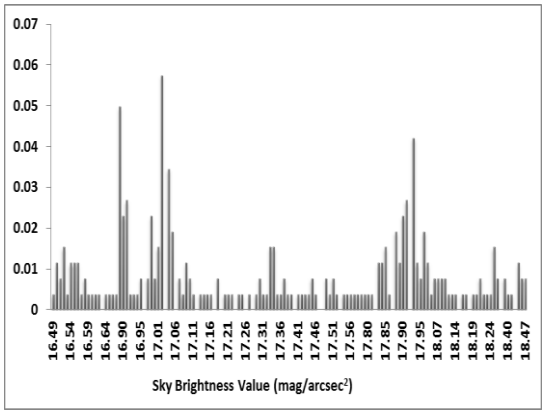

Figure 6. Full moon phase graph of probability density function

In addition, Figure 7 shows the probability density of the NSBL during the late quarter moon phase, showing that the highest probability of 5% occurs at an NSBL value of 17.27 mag/arcsec^2.

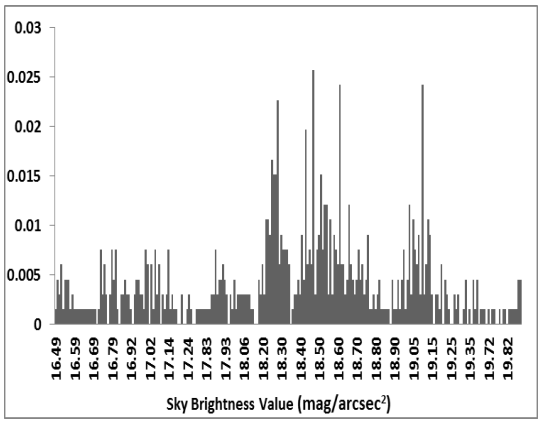

Figure 7. The last quarter moon graph of probability density function

By combining the NSBL data from all lunar phases, a compilation of the data was made, resulting in a probability distribution plot of the NSBL at Karanganyar. The highest probability NSBL value in Karanganyar is determined to be 17.22 mag/arcsec2, as shown in Figure 8. The highest recorded value reached 20.99 mag/arcsec^2, observed during the first quarter moon phase, as shown in Figure 4.

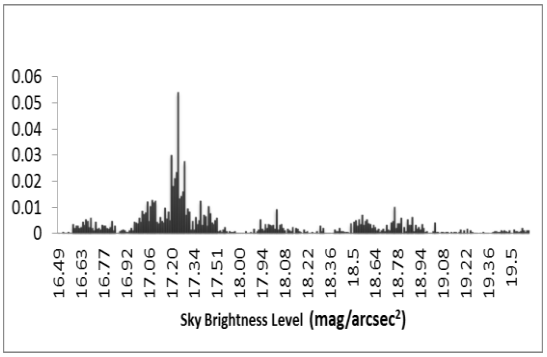

Figure 8. Night Sky Brightness profile graph

A comparison of the sky brightness values of Karanganyar obtained from NSBL measurements and satellite data is shown in Table 1. The comparison shows a difference of 4.25 mag/arcsec2 between the NSBL values of Karanganyar and those obtained from satellite data. While the SQM based NSBL values indicate high levels of light pollution, the satellite derived NSBL of 21.47 mag/arcsec2 falls into the very dark category. The SQM NSBL of 17.22 mag/arcsec2 is influenced by the overall cloudy sky conditions in Karanganyar during the December-January period.

Table 1. Comparison of NSBL

NSBL Karanganyar (mag/arcsec^2)	**Satellite NSBL** (mag/arcsec^2)
17.22	21.90

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The different NSBL data collected during the different phases of the moon indicate different probabilities. However, it is interesting to note that the NSBL values show minimal changes during the new moon phase, as shown in Figure 9. The absence of visible noise or gradients in NSBL values over time can be attributed to the position of the moon below the horizon, indicating that despite the relatively low NSBL value based on SQM measurements, lunar light pollution still dominates the sky conditions in Karanganyar.

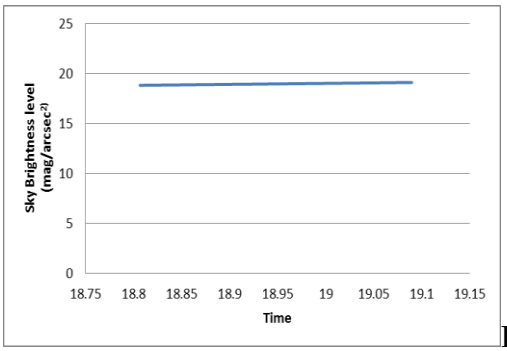

Figure 9. New moon phase NSBL chart

It is clear that the phase of the moon has a significant effect on the brightness of the sky. The highest NSBL values observed in this study are 1) during the early quarter moon phase, with a highest probability NSBL value of 17.31 mag/arcsec2 and a probability of 9% (Figure 4); 2) during the full moon phase, with a highest probability NSBL value of 17.76 mag/arcsec^2 and a probability of 5. 9% chance (Figure 6); 3) during the late quarter moon phase, with a highest probability NSBL value of 17.27 mag/arcsec^2 and a 5% chance (Figure 7); and 4) during the new moon phase, with a highest probability NSBL value of 17.22 mag/arcsec^2 and a 5% chance (Figure 5).

Data collection during the Full Moon and early Quarter phases was carried out in relatively clear weather conditions, while the New Moon phase was characterised by generally cloudy weather conditions.

The highest NSBL reading at Karanganyar during the new moon phase is 19.63 mag/arcsec2. The sky in this phase of the new moon has the category of dark sky and low light pollution, as shown in Fig. 9.

D. Conclusion

In conclusion, the measurement of night sky brightness at Karanganyar using the Sky Quality Meter (SQM) has provided valuable insights into the profile of sky brightness levels. Analysis of the Night Sky Brightness Level (NSBL) values showed that the highest probability of occurrence was 17.22 mag/arcsec2, indicating relatively dark conditions and low light pollution. Furthermore, the highest recorded NSBL value obtained from SQM measurements in Karanganyar was 20.99 mag/arcsec2, while the satellite data recorded an NSBL value of 21.9 mag/arcsec2. These results confirm that the night sky in Karanganyar is characterised

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by dark conditions and a relatively low level of light pollution. The SQM measurement method has proven to be an effective tool for assessing and monitoring the brightness of the night sky, providing valuable data for understanding and addressing light pollution concerns in the region. Further research and monitoring efforts can build on these findings to develop strategies and initiatives aimed at preserving and protecting the natural darkness of the night sky in Karanganyar.

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References

Ahyar, M., Pramudya, Y., & Okimustava. (2020). Implemestation of Visual Basic-Based Sky Quality Meter data Processing System for Analysis of Changes in Sky Brightness. *Journalof Coil Physics*, Vol.3, No.3, Hal.239-246.

Cinzano, P. (2005). Night sky photometry with sky quality meter. *ISTIL Internal Report*, *September*, 1–14. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.504.1325&rep=rep1&type=pdf

Constance, W. E., Stephen, M. P., Robert, T. S., & Erin, D. (2010). Teaching Illumination Engineering Using Light Pollution Kits. *Proceedings of SPIE*, Vol. 7783, Hal.1-11.

Damanhuri, A., & Solikin, A. (2022). Ideal Sky Quality Limits for Early Dawn Observation Locations. *Al-Marshad Journal of Islamic Astronomy and Related Sciences*, Vol.8, No.1, Hal.1-10.

Falchi, F., Cinzano, P., Elvidge, C. D., Keith, D. M., & Haim, A. (2011). Limiting the impact of light pollution on human healt, enviroment and stellar visibilty. *Journal of Environmental Management*, 1-9.

Firdaus, M. D., Rakhmadi, A. J., Putraga, H., & Hidayat, M. (2022). Analysis of The Impact of Artificial Pollution On The Brightness of The Night Sky Using a Sky Quality Meter. *Elfalaky : Journal of Falak Science*, Vol.6, No.2, Hal.197-206.

Herdiwijaya, D. (2016). Zenith Night Sky Brightness Measurement for Early

ISSN 2442-5729 (print) || ISSN 2598-2559 (online)
http://jurnal.umsu.ac.id/index.php/almarshad
DOI: https://doi.org/10.30596/jam.v9i1.13545 || Vol. 9, No. 1 Juni 2023

Dawn Determination. *SKF Proceedings* , 95-102.

Longcore, T., & Rich, C. (2004). Ecological light pollution. *The Ecological Society of America*, Hal. 191-198, Vol 2 No 4.

Luginbuhl, C. B., Walker, C. E., & Wainscoat, R. J. (2009). Lighting and astronomy. *Physics Today*, 32-37.

Miller, S. D., Straka, W., Mills, s. P., Elvidge, C. D., Lee, T. F., Solbrig, J., et al. (2013). Illuminating the Capabilities of the Suomi National Polar-Orbiting Partnershi(NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band. *Remote Sensing*, 6718-6766.

Raisal, A. Y., Pramudya , Y., Okimustava, & Muchlas. (2019). Utilization of The Moving Average Method in Determining the Early Fajr Prayer Time Using a Sky Quality Meter. *Al-Marshad Journal of Islamic Astronomy and Related Sciences*, Vol.5, No.1, Hal.1-13.

Rakhmadi, A. J., Setiawan, H. R., & Raisal, A. Y. (2020). Measurement of Light Pollution Level and Early Dawn Time at OIF UMSU using Sky Quality Meter. *Multi Sciences Scientific Journal*, Vol.12, No.2, Hal.58-65.

Ritonga, M. (2021). The Problem of Shafak and Fajar in Determining the Time of Isyak and Fajr Prayers. *Al-Marshad:Journal of Iislamic Astronomy and Related Sciences*, Vol.7, No.2, Hal.169-182.

Sukma, M., Pramudya, Y., Muchlas, & Okimustava. (2019). Night sky brightness measurement during the March 2018 Earth Hour in Yogyakarta. *Journal of Physics*, v.1231, Hal. 1-5.

Longcore, T., & Rich, C. (2004). Ecological light pollution. *The Ecological Society of America*, Hal. 191-198, Vol 2 No 4.

Luginbuhl, C. B., Walker, C. E., & Wainscoat, R. J. (2009). Lighting and astronomy. *Physics Today*, 32-37.

Miller, S. D., Straka, W., Mills, s. P., Elvidge, C. D., Lee, T. F., Solbrig, J., et al. (2013). Illuminating the Capabilities of the Suomi National Polar-Orbiting Partnershi(NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band. *Remote*

Sukma, M., Pramudya, Y., Muchlas, & Okimustava. (2019). Night sky brightness measurement during the March 2018 Earth Hour in

ISSN 2442-5729 (print) || ISSN 2598-2559 (online)
http://jurnal.umsu.ac.id/index.php/almarshad
DOI: https://doi.org/10.30596/jam.v9i1.13545 || Vol. 9, No. 1 Juni 2023

Yogyakarta. *Journal of Physics*, v.1231, Hal. 1-5.

Hänel, A., Posch, T., Ribas, S. J., Aubé, M., Duriscoe, D., Jechow, A., Kollath, Z., Lolkema, D. E., Moore, C., Schmidt, N., Spoelstra, H., Wuchterl, G., & Kyba, C. C. M. (2018). Measuring night sky brightness: methods and challenges. *Journal of Quantitative Spectroscopy and Radiative Transfer*, *205*, 278–290. https://doi.org/10.1016/j.jqsrt.2017.09.008